# THE JOURNAL

OF THE

# IRON AND STEEL INSTITUTE

## VOL. LVI.

EDITED BY

BENNETT H. BROUGH

SECRETARY

LONDON
E. & F. N. SPON, LIMITED, 125, STRAND
NEW YORK: SPON & CHAMBERLAIN, 12, CORTLANDT STREET
*SOLD ALSO AT THE OFFICES OF THE INSTITUTE*
28, VICTORIA STREET, LONDON, S.W.
1899

Printed by Ballantyne, Hanson & Co.
At the Ballantyne Press

# CONTENTS

## SECTION I.—MINUTES OF PROCEEDINGS.

PAGE
Manchester Meeting . . . . . . . . . 1
Election of Members . . . . . . . . . 5
"On the use of finely divided iron ore obtained by concentrating processes." By J. Wiborgh . . . . . . . . . 8
"On some forms of magnetic separators and their application to different ores." By H. C. McNeill . . . . . . . . . 1
Discussion of Professor Wiborgh's and Mr. McNeill's papers . . . 45
Correspondence on Professor Wiborgh's and Mr. McNeill's papers . . 50
"On a new casting-machine for blast-furnaces." By R. H. Wainford . 53
Discussion on Mr. Wainford's paper . . . . . . 58
"On the iron industry in the territory of His Highness the Nizam of Hyderabad Deccan." By S. A. Bilgrami . . . . . . . 65
"On India as a centre for steel manufacture." By R. H. Mahon . . 83
Discussion on Mr. Bilgrami's and Major Mahon's papers . . . 88
Correspondence on Mr. Bilgrami's and Major Mahon's papers . . . 89
"On practical microscopic analysis for use in the steel industries." By C. H. Ridsdale . . . . . . . . . 102
Discussion on Mr. Ridsdale's paper . . . . . . . 148
Correspondence on Mr. Ridsdale's paper . . . . . . . 157
"On pig iron fractures and their value in foundry practice." By J. W. Miller 160
"On the present position of the solution theory of carburised iron." By A. Stansfield . . . . . . . . . 169
Discussion on Dr. Stansfield's paper . . . . . . . 180
Correspondence on Dr. Stansfield's paper . . . . . . 185
"On the relation between the structure of steel and its thermal and mechanical treatment." By A. Sauveur . . . . . . . 195
Discussion on Mr. Sauveur's paper . . . . . . . 208
Correspondence on Mr. Sauveur's paper . . . . . . . 215
"On the constitution of steel." By E. D. Campbell . . . . . 223
Correspondence on Mr. Campbell's paper . . . . . . 234
Votes of thanks . . . . . . . . . . 236
"On theories and facts relating to cast iron and steel." By B. S. Summers . 240
Visits and excursions at the Manchester Meeting . . . . . 243
Obituary . . . . . . . . . . 292
Additions to the Library . . . . . . . . . 297

PAGE
Coal in Sumatra . . . . . . . . 351
The micro-organisms of coal . . . . . . . 351
III. Charcoal . . . . . . . . . . 352
Charcoal used in iron-smelting . . . . . . . 352
Gas from wood . . . . . . . . . 352
Peat charcoal . . . . . . . . 352
IV. Coke . . . . . . . . . . 352
By-product ovens . . . . . . . . 352
Coke-oven plant near Dombrau . . . . . 355
The use of coke-oven gas for illuminating purposes . . . 356
The coking of Indian coal . . . . . . . 357
Use of coke for boiler-firing . . . . . . . 357
Earliest production of coke . . . . . . . 357
V. Liquid fuel . . . . . . . . . . 358
The origin of petroleum . . . . . . . . 358
Petroleum in Russia . . . . . . . . 359
Petroleum in Roumania . . . . . . . . 360
Petroleum in Canada . . . . . . . . 361
Petroleum in California . . . . . . . . 361
Petroleum in Colorado . . . . . . . . 361
Petroleum in Japan . . . . . . . . 361
The use of petroleum in the manufacture of sheet iron . . 362
Tubes for boring . . . . . . . . 362
Petroleum motors . . . . . . . . 362
Petroleum and its flashing-point . . . . . . 362
VI. Natural gas . . . . . . . . . 364
Natural gas in Ontario . . . . . . . . 364
Natural gas at Athabasca Landing . . . . . . 364
Natural gas in Colorado . . . . . . . 364
Natural gas in Indiana . . . . . . . . 364
Natural gas in Virginia . . . . . . . . 364
VII. Artificial gas . . . . . . . . . 365
Gas-producers . . . . . . . . . 365
The Dellwik gas-producer . . . . . . . 365
Improvements in producer gas . . . . . . . 365
VIII. Coal-mining . . . . . . . . . 366
Deep boring . . . . . . . . . 366
Shaft-sinking . . . . . . . . . 367
Winding appliances . . . . . . . . 367
Steel head-frames . . . . . . . . 370
Winding-ropes . . . . . . . . . 370
Underground haulage . . . . . . . . 371
Electricity in mines . . . . . . . . 372
Coal-cutting machinery . . . . . . . . 374
Explosives and blasting . . . . . . . . 376
Methods of working coal . . . . . . . 377
Mine drainage . . . . . . . . . 377
The ventilation of collieries . . . . . . . 381

PAGE
Fire-damp outbursts . . . . . . . . 382
Fire-damp detection . . . . . . . . 383
The extinction of fire in mines . . . . . . . 383
The lighting of collieries . . . . . . . 384
Rescue appliances for collieries . . . . . . . 384
Sanitation in collieries . . . . . . . . 385
History of coal-mining . . . . . . . . 385
Mine surveying . . . . . . . . . 387
The economics of coal-mining . . . . . . . 388
Collieries in Great Britain . . . . . . . 388
Colonial collieries . . . . . . . . 388
Austrian collieries . . . . . . . . 389
The Zenica and Kreka collieries, Bosnia . . . . . 390
American collieries . . . . . . . . 392
IX. Coal-washing . . . . . . . . . 392
Coal screening and washing . . . . . . . 392
Utilisation of fine coal . . . . . . . . 393
Handling coal . . . . . . . . . 396
Peat briquettes . . . . . . . . . 397

PRODUCTION OF PIG IRON . . . . . . . . 398
I. Blast-furnace practice . . . . . . . . 398
Slips and explosions in the blast-furnace . . . . . 398
Damping down blast-furnaces . . . . . . . 398
Blast-furnace filling apparatus . . . . . . . 400
Hot blast . . . . . . . . . . 400
Blowing-engines . . . . . . . . . 400
Slag ladles . . . . . . . . . . 401
The use of blast-furnace gas . . . . . . . 401
Utilisation of blast-furnace dust . . . . . . 405
Casting machinery . . . . . . . . 405
Blast-furnace stack struck by lightning . . . . . 406
Charcoal iron furnace in Canada . . . . . . 406
The Deutscher-Kaiser ironworks . . . . . . 406
The Kraft ironworks, near Stettin . . . . . . 407
The evolution of the blast-furnace . . . . . . 408
II. Chemical composition of pig iron . . . . . . 409
Silicon and carbon in cast iron . . . . . . . 409
III. Blast-furnace slag . . . . . . . . . 410
Utilisation of slag . . . . . . . . . 410
Effect of lime and magnesia on sulphur in the blast-furnace . . 411
IV. Foundry practice . . . . . . . . . 411
Modern foundry practice . . . . . . . 411
New American foundries . . . . . . . 414
The warping of castings . . . . . . . 415
A large casting . . . . . . . . . 415
Malleable castings . . . . . . . . 415

PAGE
Pattern-making . . . . . . . . 416
Moulding . . . . . . . . 416
Cast iron pipes . . . . . . . . 416

PRODUCTION OF MALLEABLE IRON . . . . . . . 417
Manganese in the finery process . . . . . 417
History of iron . . . . . . . . 417
Composition of Swedish iron . . . . . . 418

FORGE AND MILL MACHINERY . . . . . . 420
Large forging presses . . . . . . . 420
Compressed air tools . . . . . . . 420
Large forgings . . . . . . . . 420
Rod-rolling . . . . . . . . 420
Rolling-mill fly-wheels . . . . . . . 422
Rolling rails . . . . . . . . 422
Slabbing-mill . . . . . . . . 422
New rolling-mill engines . . . . . . 422
Electric power in rolling-mills . . . . . . 423
Central steam-condensing plant . . . . . 424

PRODUCTION OF STEEL . . . . . . . . 426
I. The carburisation of malleable iron . . . . . 426
Crucible steel . . . . . . . . 426
An Austrian crucible steelworks . . . . . 432
The electric smelting of iron and steel . . . . . 434
II. The open-hearth process . . . . . . . 434
Improving open-hearth steel . . . . . . 434
Open-hearth furnaces at Barrow . . . . . 437
Open-hearth plant at Hayange . . . . . . 437
American open-hearth steelworks . . . . . 437
III. The Bessemer process . . . . . . . 438
The Barrow Steelworks . . . . . . . 438
The South Chicago Bessemer works . . . . . 439
A Japanese steelworks . . . . . . . 440
Registering speed of blowing-engines. . . . . . 442
The Bertrand-Thiel process . . . . . . 442
Combined Bessemer and puddling process . . . . 443
Basic slag . . . . . . . . 443
The use of carbide of silicon . . . . . . 443

FURTHER TREATMENT OF IRON AND STEEL . . . . . 445
Damask steel . . . . . . . . 445
Electric welding . . . . . . . . 445
The manufacture of propeller shafts . . . . . 446
Forging wrought-iron axles . . . . . . 446
The manufacture of anvils . . . . . . 447
Seamless tubes . . . . . . . . 447

PAGE
Cast-steel bells . . . . . . . . . 447
Railway waggons . . . . . . . . 447
Steel dam for a reservoir . . . . . . . 448
The new East River suspension bridge . . . . 448
Ornamental ironwork . . . . . . . . 448
Cold process galvanisation . . . . . . . 449
The manufacture of tin plates . . . . . . . 449
Enamelled iron ware . . . . . . . . 450
Workshop at the Charlottenburg Technical High School . . 450

PHYSICAL PROPERTIES . . . . . . . . . 451
The microstructure of iron . . . . . . . 451
Physical analysis of steel . . . . . . . 451
The texture of iron . . . . . . . . 451
Magnetic properties of iron and steel . . . . . 453
Theory of deformation of metals . . . . . 457
The effect of temperature on the strength of iron and steel . . 458
Iron alloys . . . . . . . . . 461
Alloys of iron and nickel . . . . . . . 462
Radiographic examination of steel plates . . . . . 465
The effect of punching and shearing . . . . . 465
Torsion and recalescence of steel . . . . . 466
Eolotropy in steel . . . . . . . . 466
Internal strains in steel . . . . . . . . 466
Testing machines . . . . . . . . 466
Standard tests of cast iron . . . . . . . 467
Transverse tests of cast iron . . . . . . . 468
Tests of steel . . . . . . . . . 469
Testing bicycle tubing . . . . . . . . 469
Test of wire rope . . . . . . . . 470
Wheels . . . . . . . . . . 470
Rails . . . . . . . . . . 470
Tests of armour-plates . . . . . . . . 471

CHEMICAL PROPERTIES . . . . . . . . . 473
The rusting of iron . . . . . . . . 473
The corrosion of iron . . . . . . . . 473
Action of sea-water on iron . . . . . . . 474
Action of water on galvanised iron . . . . . 474
Ferrosilicon . . . . . . . . . 474
Aluminium as a reducing and heating agent . . . . 475
Science and iron-smelting . . . . . . . 477

CHEMICAL ANALYSIS . . . . . . . . . 480
I. Analysis of iron and steel . . . . . . . . 480
Metallurgical analysis . . . . . . . . 480
Standards for iron analysis . . . . . . . 480
Determination of iron . . . . . . . . 482

PAGE
Determination of carbon . . . . . . . 482
Determination of silicon . . . . . . . 484
Determination of sulphur . . . . . . . 484
Determination of nickel . . . . . . . 487
Determination of titanium and vanadium . . . . 489
II. Analysis of iron ore . . . . . . . . . 489
Determination of iron . . . . . . . . 489
Determination of sulphuric acid . . . . . . 490
Determination of phosphoric acid in basic slag . . . 491
III. Fuel analysis . . . . . . . . . 492
Analysis of coal . . . . . . . . . 492
Determination of sulphur in coal . . . . . . 492
Determination of sulphur in Roumanian petroleum . . . 492
IV. Gas analysis . . . . . . . . . 493
Determination of oxygen . . . . . . . 493

STATISTICS . . . . . . . . . . . 494
I. United Kingdom . . . . . . . . . 494
Mineral statistics . . . . . . . . 494
Iron trade statistics . . . . . . . . 494
Blast-furnace statistics . . . . . . . 495
Ship construction . . . . . . . . 495
Consumption of coal . . . . . . . . 495
II. Australasia . . . . . . . . . 496
Mineral statistics of New South Wales . . . . . 496
Mineral statistics of Victoria . . . . . . 496
III. Austria-Hungary . . . . . . . . . 496
Mineral statistics . . . . . . . . 496
Accidents in mines . . . . . . . . 496
Iron trade exports and imports . . . . . . 497
Ironworks in Bohemia . . . . . . . . 498
Brown coal in Bohemia . . . . . . . . 499
Production of petroleum . . . . . . . 500
Production of ozokerite . . . . . . . 500
Hungarian mineral statistics . . . . . . 500
Mineral statistics of Bosnia and Herzegovina . . . . 500
IV. Belgium . . . . . . . . . . 502
Mineral statistics . . . . . . . . 502
Blast-furnaces . . . . . . . . . 502
Mines in Belgium . . . . . . . . 503
V. Canada . . . . . . . . . . 503
Mineral statistics . . . . . . . . 503
Iron-smelting in Canada . . . . . . . 504
VI. France . . . . . . . . . . 504
Iron trade statistics . . . . . . . . 504
Blast-furnaces . . . . . . . . . 504
Algerian iron ore . . . . . . . . 505

PAGE
VII. Germany . . . . . . . . . . 505
Imports and exports . . . . . . . . 505
Mineral statistics of Prussia . . . . . . . 506
Mineral statistics of Upper Silesia . . . . . . 506
Mineral statistics of Bavaria . . . . . . . 508
Krupp's works . . . . . . . . . 508
Coal and coke . . . . . . . . . 508
Mineral statistics of Luxemburg . . . . . . 510
VIII. Greece . . . . . . . . . . 510
Mineral statistics . . . . . . . . 510
IX. India . . . . . . . . . . 511
Production of coal . . . . . . . . 511
Iron manufacture . . . . . . . . 512
X. Italy . . . . . . . . . . 514
Mineral statistics . . . . . . . . 514
Iron ore in Elba . . . . . . . . 514
The iron industry of Lombardy . . . . . . 515
XI. Russia . . . . . . . . . . 516
The iron industry . . . . . . . . 516
Manganiferous pig iron industry . . . . . . 518
The coal industry . . . . . . . . 519
The Southern Ural mining industry . . . . . . 519
XII. Spain . . . . . . . . . . 520
Iron trade statistics . . . . . . . . 520
Imports and exports . . . . . . . . 520
XIII. Sweden . . . . . . . . . . 520
Iron trade statistics . . . . . . . . 520
Shipments of iron ore . . . . . . . . 521
Production of coal . . . . . . . . 521
Swedish iron metallurgy and its application to Canada . . . 522
XIV. Switzerland . . . . . . . . . 522
Production of coal . . . . . . . . 522
XV. United States . . . . . . . . . 523
Iron trade statistics . . . . . . . . 523
Mineral statistics . . . . . . . . 523
Blast-furnaces . . . . . . . . . 523
Iron ore in Michigan . . . . . . . . 524
Coke production . . . . . . . . . 524
Conditions of the iron and steel industries . . . . . 524
Metallurgical education . . . . . . . 524
XVI. Comparative tables . . . . . . . . 525
The world's production of coal and iron . . . . . 525
The world's production of steel . . . . . . 526
The world's production of iron ore and pig iron . . . . 526
The world's production of manganese ore . . . . . 527
The world's production of petroleum . . . . . 528
The world's railways . . . . . . . . 528

PAGE
BIBLIOGRAPHY . . . . . . . . . . 530
Metallurgy . . . . . . . . . 530
Mining . . . . . . . . . 531

INDEX . . . . . . . . . . 533

## LIST OF PLATES.

I. Reducing furnace for pulverulent ores . . . . . . 16
II. The Wainford casting-machine . . . . . . . 64
III. to XIV. Photographs illustrating Mr. Ridsdale's paper . . . 144
XV. Changes in microstructure brought about in steel by heat treatment . 208

# THE
# IRON AND STEEL INSTITUTE.

## SECTION I.

## *MINUTES OF PROCEEDINGS.*

### MANCHESTER MEETING.

The AUTUMN MEETING of the IRON AND STEEL INSTITUTE was held at the Town Hall, Manchester, on Tuesday, August 15, 1899—Sir WILLIAM C. ROBERTS-AUSTEN, K.C.B., President, in the chair.

The LORD MAYOR (W. H. VAUDREY), in gracefully welcoming the Institute to Manchester, said: It is my pleasing duty this morning to give a hearty welcome to the Iron and Steel Institute on their visit to Manchester. You paid us a visit first in 1875, and again in 1887; and now I am pleased to have the opportunity and the pleasure, as Lord Mayor of this city, of once more giving you the use of the Town Hall. Your Institute is an important one, numbering something like 1700 members. I quite recognise that a large commercial community like Lancashire ought to welcome a visit from you. We are, as you all know, a hard-working, industrious population in this big county. We have a number of towns, and in each of our towns work is done for the benefit of the commercial community —in nine cases out of ten in connection with engineering. In your President this year, Sir William Roberts-Austen, you have a man who has made his name at the Royal Mint. I am perfectly sure that in that choice you have exercised a wise discretion, and I welcome Sir William here to-day as your President. It is the privilege of the Lord Mayor, on behalf of this city, to extend hospitality to all Associations when they visit our city, and in this capacity I am pleased to have the honour of being present here to-day, and extending to you the hospitality of this Town Hall.

Mr. S. R. PLATT, Vice-President, the chairman of the Executive Committee, said that it was his suggestion that the Institute, after an interval of twelve years, should return to Manchester, and he had been very pleased to find the proposal adopted. The arrangements having been placed in his hands, he had immediately put himself in communication with the Lord Mayor, who at once promised that he would do all he could, and that the Corporation would give them a most hearty and cordial welcome. His next labour was to call together a committee of Manchester engineers and others interested in the iron and steel trade, and when he had done so, he was delighted with the absolutely unanimous support which they gave to the proposal. The guarantee fund was over-subscribed, and he hoped, as a result, that they would find that they had had provided for them a week of choice entertainment as well as of instruction, seeing that no effort had been spared to attain this object. In conclusion, he thanked his committee and Mr. Ashbury, the secretary, for the very faithful and cordial way in which they had arranged the business. He thought that after the meeting concluded the Institute would not forget the way in which they had been received by the citizens of Manchester.

The PRESIDENT, in reply, said: My Lord Mayor and Gentlemen,—It has long been the custom for the Iron and Steel Institute to hold an autumn meeting in some great industrial centre, either in this or in other countries. Last autumn we went to Stockholm. Sweden may be called the home of the iron and steel industries, and is a country to which England owes a great deal. But it is well that we should meet here for the last autumn meeting which will be held in these islands within the limits of the century, for next year, as most of you know, we have been invited to go to Paris; it is, therefore, singularly fitting that we should meet in a great city which is so pre-eminently remarkable for the mechanical applications of iron and steel to engineering operations and to appliances used in manufacture. This is not the first time, as we have been reminded, that we have visited this great city. Many who are here present will remember the warmth and the magnificence of the reception which the city gave us no less than twenty-four years ago. But there is another reason why we should meet in Manchester. Although the iron and steel industries are eminently practical in their character, they rest upon a scientific basis; and Manchester has had two citizens of whom any city in the world might be justly proud. I need hardly say that I refer to Dalton and to Joule. It was in 1803 that Dalton propounded his great system of atomic weights, a system on which the whole of chemical analysis is based; and I need hardly ask you where the iron and steel industries would be without the aid that is given to them by chemical analysis. Joule, on the other hand, in a memorable investigation established the "mechanical equivalent of heat," on which, it is not too much to say, every indicator diagram rests. I well remember the pride with which, coming to this city in 1868 as a young man with a distinguished Russian, his Excellency M. de Jacobi of St. Petersburg, well known from his connection with the electro-deposition of copper and with the use of the first torpedo. Directly we arrived in this city, I took him to pay our homage at the feet of Joule. We are proud to place by the side of such names as Dalton and Joule those of our illustrious dead; and I need only mention Cort, Neilson, Nasmyth, Bessemer, and Siemens. You will remember the names of other great men, some of them still with us; but I will add the names of the great engineers of Manchester, Whitworth, Daniel Adamson, and Fairbairn. I would name others, but the list would be too numerous, and the names of Manchester's illustrious men will occur to all those present. There is one other reason why we should meet in Manchester; it possesses a great college, Owen's College, the professors of which are famous throughout all the world. This great college occupies not only a prominent place in the scheme of technical instruction, which is of such vital importance to our country, but it holds a high position in connection with the great Victoria University, the type of the universities which are being founded throughout our land.

The mention of the beloved and venerated name of Queen Victoria reminds me, my Lord Mayor, that since we met in London as an Institute, I and two of our Past-Presidents with our Secretary were summoned to Windsor to offer to Her Majesty, Queen Victoria, the Bessemer medal of our Institute. The gracious words Her Majesty addressed to us in accepting that medal are deeply engraven in our memories, for they consecrate, as it were, the efforts which have been made by Members of our Institute to perfect the products of the great industry we represent. They consecrate, I may add, the efforts which have so greatly contributed to promoting the welfare of the Empire, and in sustaining the glory of Her Majesty's reign over the nation that formed "the Age of Steel." You will see the effigy of Her Gracious Majesty on our badges this year. Long may Her Majesty's reign be prolonged.

Now, my Lord Mayor, I come to the few words of thanks. Inadequate they must be, for although we have only been in Lancashire for a few hours, we see already what elaborate preparations you have made, and what kind efforts you have devoted to ensuring in every possible way our enjoyment in your city and our interest in your works. We are most grateful, not only to you and to the committees who have worked so strenuously, but to Mr. Platt who has directed them, and to Mr. Ashbury, on whom so much of the work has devolved. At present I am only deferring to the end of what must be a delightful meeting a few more thanks—thanks which are already finding expression on all sides, and which we shall have an opportunity of presenting later on. My Lord Mayor, in these few words I offer you our sincere thanks for the hospitality you have promised us.

The SECRETARY read the minutes of the previous meeting, which were confirmed.

The SECRETARY announced that, in accordance with Rule 10, the members of the Council who will retire by rotation in May next, are Mr. James Riley, Mr. William Henry Bleckly, and Mr. Andrew Carnegie, Vice-Presidents; and Mr. Adolphe Greiner, Mr. John Devonshire Ellis, Mr. Robert Abbot Hadfield, Sir Benjamin Hingley, and Mr. William Beadmore, members of the Council. All these gentlemen were eligible for re-election. It was competent for members to nominate candidates for office up to one month previous to the general meeting.

Mr. E. Graham Wood (Manchester) and Mr. T. M. Percy (Wigan) were nominated scrutineers, and on the completion of their scrutiny announced that the following gentlemen had been duly elected members of the Institute:—

| NAME. | ADDRESS. | PROPOSERS. |
|---|---|---|
| Adamson, Harold . . | Hyde, near Manchester | Joseph Adamson, Henry Webb, Wm. Dronsfield. |
| Baackes, Frank . . . | The Rookery, Chicago, U.S.A. | F. H. Daniels, Robert W. Hunt, Arvid Lindman. |
| Barton, Albert Edward | Carnforth | Edward Barton, Joseph Gregory, Thomas Ashbury. |
| Bloomer, Clifford Edward | Haywood Forge, Halesowen | Sir Benjamin Hingley, George Hatton, Walter Somers. |
| Bréda, Louis . . . | 32 Rue de l'Eglise, Koekelberg, Bruxelles | H. Ponthière, Emile Lelong, Sir William C. Roberts-Austen. |
| Broms, Gustaf Emil . | Stockholm | William Whitwell, Edward P. Martin, E. Windsor Richards. |
| Broms, Otto . . . . | Stockholm | William Whitwell, Edward P. Martin, E. Windsor Richards. |
| Brophy, Michael M., M.I.Mech.E. | 251 High Holborn, London, W.C. | Joseph Adamson, Henry Webb, Wm. Dronsfield. |
| Burt, George . . . | 37 Grosvenor Road, London, S.W. | Thomas Wrightson, William Anderson, Septimus Young. |
| Coldwell-Horsfall, Henry Herbert | Hay Mills, near Birmingham | Arthur Keen, James Rollason, Charles Hunt. |
| Davies, John C. . . | Wood Green, Wednesbury | Enoch James, William Roberts, Lincoln Chandler. |
| Dawson, Robert. . . | Park Hill, Millbrook, Stalybridge | E. T. Atkinson, Thomas Ashbury, Robert B. Barningham. |
| Donald, David Patrick | Johnstone, Renfrewshire, N.B. | Edgar J. Windsor Richards, James Kerr, Andrew C. Patrick. |
| Douglas, James . . . | 99 John Street, New York, U.S.A. | Sir David Dale, Sir William C. Roberts-Austen, Edward P. Martin. |

| Name. | Address. | Proposers |
|---|---|---|
| Evans, John | 24 Hartington Street, Barrow-in-Furness | J. M. While, Sir William T. Lewis, Edward P. Martin. |
| Farrar, William | 72 Steade Road, Sheffield | Joseph Jackman, David Evans, Frederick H. Brooke. |
| Flagg, Stanley Griswold, Jun. | 19 Pennsylvania Avenue, Philadelphia, U.S.A. | R. A. Hadfield, A. G. M. Jack, J. E. Stead. |
| Flather, David | Standard Steel Works, Sheffield | Robert Schott, John D. Ellis, W. T. Flather. |
| Gamble, Arnold | Gamston Manor, Retford | John D. Ellis, Samuel Osborn, Joseph Gamble. |
| Hodgson, Henry | Guide Bridge Iron Works, Guide Bridge, near Manchester | Henry Webb, Thomas Ashbury, Samuel Dixon. |
| Johnston, William Joseph | The Hollies, 214 Barnsley Road, Pitsmoor, Sheffield | Harry Marsden, Rudolf L. Leffler, T. W. Willis. |
| Jones, James | Velindre, Wood Green, Wednesbury | Enoch James, Chas. J. Bagley, J. W. Wainwright. |
| Kestranek, William | 1 Krugerstrasse 16, Vienna | Sir William C. Roberts-Austen, E. Windsor Richards, David Evans. |
| Klein, Jacob | South Parade, Manchester | Andrew Lamberton, George Garrett, George Russell. |
| Lester, Isaac E. | East Indian Railway, Jamulpur, India | T. Twynam, Alex. E. Tucker, F. W. Harbord. |
| Lintern, William Turner | 3 Bellott Street, Cheetham, Manchester | John H. Darby, P. Williams, A. Patterson. |
| Macfarlane, John | 98 Bath Street, Glasgow | John Colville, T. B. Rogerson, William Muirhead. |
| Main, James A. | Clydesdale Iron Works, Possilpark, Glasgow | John Colville, T. B. Rogersson, William Muirhead. |
| Milne, Isaac Bernard | 400 Firth Park Road, Sheffield | R. A. Hadfield, A. G. M. Jack, J. E. Stead. |
| Mordey, W. M. | 82 Victoria Street, London, S.W. | R. A. Hadfield, Edward P. Martin, E. Windsor Richards. |
| Morgans, John T. | 2 Morlais Street, Dowlais, Glamorganshire | Edward P. Martin, Alfred Bowen, D. R. Jones. |
| Norris, Charles Guest | Mottram, near Manchester | Sir William H. Bailey, John M. Gledhill, William H. Fowler. |
| Nowlan, John, Assoc. M.Inst.C.E. | Pillgwenlly Foundry and Engineering Works, Newport, Mon. | Edward P. Martin, H. J. Butter, Edward T. Agius. |
| Owen, Thomas, M.I. Mech.E. | Midland Railway Company, Derby | Sir Alexander Wilson, Henry Steel, Jun., William Tozer. |
| Petley, William, Assoc. R.S.M. | Pedmore Lodge, Stourbridge. | Sir William C. Roberts-Austen, George J. Snelus, R. A. Hadfield. |
| Platt, John, M.Inst. C.E. | Salford Iron Works, Manchester | John A. F. Aspinall, Edward P. Martin, Arthur Keen. |
| Porter, John Bonsall | McGill University, Montreal, Canada | Sir William C. Roberts-Austen, George J. Snelus, J. E. Stead. |

| NAME. | ADDRESS. | PROPOSERS |
|---|---|---|
| Poulaine, Eugène . . | Blaina House, Blaina, R.S.O., Mon. | Edward P. Martin, W. A. Scrivener, Isaac Butler. |
| Redaelli, Pietro. . . | Castello, near Lecco, Italy | Herbert Barber, William Tozer, G. Gerhard Coppel. |
| Ridley, Alfred Forbes | Königshof, bei Beraun, Austria | Edward Riley, David Evans, Arthur Cooper. |
| Rollin, Francis Thomas . . . . | 185 Penistone Road, Sheffield | Thomas Wilkinson, Robert B. Maltby, A. Firth. |
| Sandberg, A. O. F. . | 9 Bridge Street, Westminster, London, S.W. | C. P. Sandberg, Edward P. Martin, E. Windsor Richards. |
| Sandford, William . | Eskbank Rolling Mills, Lithgow, N.S.W. | Alfred Hewlett, David Evans, John H. Darby. |
| Scott, Charles . . . | Guide Bridge Iron Works, near Manchester | Henry Webb, Thomas Ashbury, Joseph Adamson. |
| Scott, Frederick George . . . . . | Preston, North Shields | H.W. Hollis, Robert Hedley, George Ainsworth. |
| Smith, William . . . | Sycamore Park Road, Moseley, Birmingham | Thomas Wilkinson, Ambrose Firth, J. H. Barber. |
| Snelus, George James, Jun. . . . . . . | 99 Rue de l'Industrie, Seraing, Belgium | Sir William C. Roberts-Austen, Edward P. Martin, Sir David Dale. |
| Stansfield, Alfred, D.Sc., Assoc. R.S.M. | Royal School of Mines, South Kensington, London, S.W. | Sir William C. Roberts-Austen, George J. Snelus, R. A. Hadfield. |
| Sykes, Edwin . . . | 1 St. Andrews Road, Aspley, Huddersfield | Ezra Sykes, Horace Broadbent, Joseph Adamson. |
| Tudhope, James . . | Crown Iron Works, Coatbridge, N.B. | George Garrett, Andrew Lamberton, Sir William C. Roberts-Austen. |
| Turnbull, Nicholas King, Assoc. M. Inst. C.E. . . . . . . | Bradford Iron Works, Manchester | Fred. W. Paul, F. W. Llewelyn, Herbert A. Johnson. |
| Veith, Béla . . . . | Hernad Iron Company, Budapest, Hungary | George Hatton, John H. Darby, Edward P. Martin. |
| Wood, Daniel . . . | Norwood, Hastings Avenue, Chorlton-cum-Hardy, Manchester | Sydney J. Robinson, Henry Webb, Thomas Ashbury. |

The following paper was then read by Mr. H. Bauerman :-

# THE USE OF FINELY-DIVIDED IRON ORE OBTAINED BY CONCENTRATING PROCESSES.

By Professor J. WIBORGH, Stockholm. Translated by H. BAUERMAN, F.G.S.

By the introduction of magnetic and other methods of separation, the power of enriching or improving iron ores, by the removal of barren or undesirable constituents, has been greatly increased; and by the use of such methods the waste in working, in the case of magnetic minerals at least, can be considerably diminished. The advantage arising from such operations is, however, largely qualified by the circumstance that the product or concentrate is usually obtained as a comparatively fine powder, which limits its utility to the smelter when compared with that of similar or even poorer ores obtained in larger masses, and therefore the question of how such material can best be applied is now becoming of importance. As a contribution to the knowledge of the subject, the present paper, giving the views of one of the most experienced Swedish iron chemists, cannot fail to be of interest to the members of the Institute.

Powdered iron ores obtained by concentration may be utilised in several different ways, namely—

I. By direct addition to the charges in the blast-furnace.
II. By agglomeration previously to charging in the blast-furnace.
III. As a refining or softening material in the open-hearth furnace
IV. For the production of sponge iron for use in the open-hearth furnace; which uses will be considered in the above order.

## I.—Direct Use in the Blast-Furnace.

The proportion of small ore that can be used in the blast-furnace is subject to variation according to the conditions of fuel and working, but cannot, in most instances, be very large, limits being imposed by the tendency of the material, especially if it is of high density, such as pulverised magnetite, to overrun the fuel charge and come down to the tuyeres in an imperfectly reduced condition, as well as to form accretions or scaffolds by adhesion to the furnace walls above the hearth. As an example of the behaviour of concentrates, the results of experiments made in 1898 at the blast-furnace at Vidlitz, in the government of Olonetz, in Russia, will be given. These were conducted by Dr. H. Blankett, an experienced metallurgical engineer and graduate of the School of Mines in Stockholm. The materials smelted included concentrates obtained by magnetic separation from a lean magnetite at Valimäki, in Finland, poorer magnetic ore in lumps from the same place, and bog ores from Taipala, of the following composition:—

| | Ore Concentrate, Valimäki. | Lump Ores, Valimäki. | Bog Ore, Taipala. |
|---|---|---|---|
| $Fe_2O_3$ . . . . | ... | ... | 48·30 |
| $Fe_3O_2$ . . . . | 72·32 | 51·48 | ... |
| $SiO_2$ . . . . | 11·26 | 21·70 | 19·74 |
| $TiO_2$ . . . . | 4·65 | 7·40 | ... |
| $Al_2O_3$ . . . . | 4·81 | 2·07 | 2·47 |
| MnO . . . . | 0·19 | 0·13 | 4·72 |
| CaO . . . . | 4·00 | 7·65 | 1·81 |
| MgO . . . . | 4·42 | 8·14 | trace |
| P . . . . . | trace | 0·03 | 0·87 |
| S . . . . . | 0·99 | trace | 0·09 |
| $H_2O$ . . . . | ... | ... | 20·00 |
| Metallic iron . . | 52·06 | 37·06 | 33·79 |

Cold blast was used during the trials, the regenerative heating stoves being under reconstruction, and the proportion of concentrate in the charge was gradually increased. Under these conditions no scaffolding was observed, but the descent of the charge was often irregular, with the result of chilling and gobbing the furnace. This irregularity was most apparent when a charge of small-sized charcoal was followed by one or more of larger pieces; and when care was taken to ensure better sizing of the fuel, the furnace drove more regularly, and in the week from the 18th to the 25th of April 1898 (O.S.), the ore concentrate was smelted alone without the occurrence of any such irregularity.

From this it appears that in the smelting of rich and heavy concentrates, the coal should be used in smaller pieces than is necessary with finer materials of a less dense character, such as lake and bog ores, purple ore, &c. This combination can, however, only be successfully handled in furnaces of small height, as in a tall furnace the close packing of the charge is necessarily attended with slow driving and unduly large production of carbon monoxide, from the prolonged contact of the gas from the reducing zone with the fuel above.

*Irregularity due to Adhesion of Ore to Stack Wall or Scaffolding.*—It is a matter of general experience that finely-divided ore and ore dust readily adhere to the heated wall of the furnace, and gradually accumulate into large masses, which, falling into the region of the hearth when detached by the pressure of the column of materials above them, meet with an insufficient body of fuel to effect their complete fusion, with the result of producing "cold" iron or choking. This tendency to form accretions or scaffolds is the principal cause restricting the use of powdered ore in large quantity in blast-furnaces, but there are certain distinctions to be made; thus the tendency to scaffolding is greater with small than with large ore, with small-grained ores of equal size it is greater with those of lower than higher density, and with those containing fusible minerals greater than with those carrying waste constituents of a refractory character. Other conditions influencing the result are the greater or less steepness of the bosh walls and the more or less refractory character of the materials used in the stack lining. In the case previously referred to at Vidlitz, the slope of the boshes above the tuyeres was 75°, which at a higher level was reduced to 70°, a section which would *a priori* be considered as extremely unsuitable for the use of powdered ore. Nevertheless the furnace worked satisfactorily even on concentrates alone, so long as cold blast was used. When, however, the stoves were repaired, and the blast was heated to 450° or 500° C., scaffolding began, and continued with little alteration until the hearth and tuyeres were burnt out, and no improvement was experienced even by reducing the proportion of concentrate in the charge to 30 per cent. The difficulty was attributed to the intense local heating of the hearth and boshes by the blast, causing the finely-divided ore to stick to the wall of the furnace, but it was considered that the fine dust of the bog ore was a greater source of trouble than the dense magnetite.

As a preventive of scaffolding with the materials under consideration, furnaces with cylindrical stacks or a bosh angle of 90° have been suggested, but it is easy to see that the use of such a section would be attended with considerable difficulties. Notably the furnace must either be of small dimensions, or, if of a large capacity, it would be unreasonably wide, and the rapid driving necessitated by such a form would be suitable to the production of pig iron for forge use, or the production of malleable castings rather than a more siliceous or manganiferous metal; and even though magnetic concentrates may be somewhat more easily reducible than similar ores in lump form, it is doubtful whether it could be advantageously used under the conditions of forced driving called for by the cylindrical form of stack.

Rich and heavy concentrates or small ores have, however, been used without difficulty on several occasions; as, for example, at the old works of Högfors, where concentrates obtained by washing from the leaner ore of Norberg were used to the extent of 30 per cent., and at the Baggå furnace of 25 per cent., the latter being obtained by magnetic separation with the Gröndahl separator. Certain ores from Grängesberg, when crushed after roasting, also readily fell to pieces, but no great inconvenience has been experienced in them. The author is, therefore, disposed to consider that the addition of concentrates up to about 50 per cent. of the charge may be regularly carried out in furnaces with a bosh angle of 83 to 84 degrees. The washing of powdered ore with a view to increasing its reducibility is of less consequence than with the same ore in lumps, except, of course, when it contains sulphur, when it becomes necessary. At Baggå the concentrates are roasted in a small reverberatory furnace. Another inconvenience attending the use of powdered ore is the loss caused by dust in the gases, and in this respect the cylindrical stack would be most disadvantageous on account of the velocity of the upward current in the stack, which would necessarily be greater than in a furnace of smaller bosh diameter. At Vidlitz, when the charge consisted of magnetic concentrates and bog ore only, from 8 to 10 per cent. of the powdered ore was carried over into the gas conduits.

## II.—AGGLOMERATION BEFORE SMELTING IN THE BLAST-FURNACE.

In order to avoid the inconveniences attending the use of small ore in the blast-furnace, numerous methods have been proposed and tried, more or less successfully, for consolidating it into coherent masses or lumps as a preliminary to smelting. This may, in certain cases, be done without the addition of foreign matter, but, as a general rule, some binding material is required. There is a tolerably wide range of choice among the substances that can be used for this purpose. One condition, however, is necessary, namely, that nothing shall be used that would be injurious either to the product or detrimental to the working of the furnace, which excludes such a substance as gypsum, as likely to introduce sulphur into the iron, or magnesium chloride, which, by bringing chlorine or hydrochloric acid into the blast-furnace gas, would be destructive to the iron work of the stoves and boilers.

The principal methods that have been practically tried are as follows:—

*Agglomeration by Heat alone without Binding Material.*—Powdered ores that are not particularly rich and contain easily fusible silicates, such as hornblende or pyroxenic minerals, may be made to cohere by heating in a reverberatory furnace up to the point necessary to produce incipient fusion of these accessory minerals; but to obtain a similar result with rich magnetic concentrates, it would be necessary first to mix them with such a material; as, for instance, with easily fusible blast-furnace slag. Such methods are, however, costly, as the temperature to which the mixture must be heated is higher, and the time required is longer, than is necessary in the ordinary method of ore calcining. They have been used at the Cornelia mine at Stollberg, and at Valimäki in Finland. The powdered ore is mixed with water, and the damp mass is moulded into bricks, which, when dried, are sufficiently coherent to be charged into kilns and burn to masses of considerable strength and hardness. The best results are obtained when the ore, which should be in a very fine powder, is not very rich, containing 50 or at most 60 per cent. of iron, the remainder being fusible silicates. This has also been tried experimentally at Vidlitz, the mixture being moulded into small cylindrical masses, which are burnt with charcoal dust in the Schedinska kiln, which is generally used in the locality for calcining iron ores. At Stollberg the finely-powdered ore obtained by washing was moulded into bricks and subsequently burnt.

*Consolidation of Small Ore with Lime.*—Caustic or slaked lime tempered to a stiff paste with water is the best binding material for powdered iron ores, especially for those containing a notable amount of iron silicates or silica. Briquettes made with such materials become harder by continued exposure to the air, first by the conversion of the lime into carbonate and subsequently into silicate, and the intimate mixture of the reducing and fluxing material in the mass tends to facilitate working in the blast-furnace. For this latter reason, in the treatment of differently reducible silicates, such as heating furnace slags, it is sometimes found convenient to grind them to powder and mix them with lime and some charcoal dust into briquettes, in order to furnish a slag suitable for smelting in the blast-furnace.

*Agglomeration of Ore with Carbonaceous Material and Coking.*—It has long been known that pulverulent materials, when mixed with tar, pitch, or bituminous coal and strongly heated, give, when cooled, hard and compact masses. This was applied by Weissmann about ten years ago in the production of so-called ore coke, which was made by mixing powdered ore with 20 per cent. of coal-dust and 5 per cent. of pitch, pressing the mixture into blocks, which were coked at a strong heat applied slowly. This, however, proved to be too expensive for practical use, but the idea has been revived in a simpler form, namely, mixing small coal and powdered ore together, and coking the mixture in the ordinary way. Experiments in this direction, made at the suggestion of Mr. Carl Ericsson, by Mr. C. C. Dalerus at the Islinge coke works with the concentrated magnetite, obtained at the Luleå apatite separating works, have given remarkably good results. The powdered ore, averaging about 1 millimetre in the size of the grains and containing about 70 per cent. of iron, when mixed with 30 to 40 per cent. of coal gave a product which was hard and compact, and could be quenched with water in the same way as ordinary coke of good quality. By coking, the ore was reduced to ferrous oxide with some metallic iron, and showed no great tendency to pass into a higher state of oxidation even when exposed to the air for a considerable time. With easily reducible ores, however, it is probable that there would be a larger production of metallic iron which would readily oxidise when quenched with water, or by long exposure to the atmosphere, with the result of diminishing the strength of the coke.

The author is, however, favourably impressed with the results of the experiments made in Germany upon ore coking, owing to the simplicity of the method, and has considered the subject from the thermo-chemical point of view, in order to determine the possible heat requirements of the process.

The unit of magnetite contains iron 0·7242 and oxygen 0·2758, and as the unit of oxygen in the conversion of iron to magnetite develops 4326 cals., the heat absorption in the reduction of a unit of magnetite to metallic iron will be $4326 \cdot 0 \times 2758 = 1194$ cals.; while the reduction, if effected with carbon, will consume $\frac{1}{16}0 \times 2758 = 0 \cdot 207$ of carbon, producing $\frac{28}{16}0 \times 2758 = 0 \cdot 482$ of carbon monoxide, and developing $2473 \times 0 \cdot 207 = 512$ cals., or a heat deficiency of $1194 - 512 = 682$ cals. The carbon monoxide produced is, however, susceptible when burnt of developing $2403 \times 0 \cdot 482 = 1158$ cals., so that the final result will be $1158 - 682 = 476$ cals. available for heating the flues and walls of the oven per unit of magnetite reduced. These, however, are extreme figures, as they suppose complete reduction of the ore, which is not likely, the temperature prevailing in coke-ovens not being sufficiently high; but any degree of reduction will be attended with some loss of fixed carbon, which, however, it may be supposed, will be compensated by a diminished consumption of fuel in the blast-furnace; but, as far as the author knows, no actual smelting trials of such ore coke have been made up to the present.

Among the causes likely to produce irregularities in working may be mentioned: the difficulty of so mixing the ore and coal as to ensure a product of uniform richness; the probability that such mixtures would contract less than coal alone in coking, so that there might be trouble in drawing the charge; and the scorifying effect of the ore dust upon the heated brickwork of the oven; while in the smelting furnace the possibility of such coke coming down the tuyeres unchanged with a partial combustion of the contained iron as well as of the carbon has to be considered. But, as has been before stated, experimental evidence upon such points is entirely wanting.

## III.—USE OF POWDERED ORE IN THE OPEN-HEARTH FURNACE.

Experiments on the substitution of powdered for lump ore in the open-hearth furnace were made by Dr. H. Tholander in the basic open-hearth furnace at Hofors in September 1897. The material used was the concentrated ore from the Luleå magnetic separating works, which contains 72 per cent. of iron and 0·1 per cent. phosphorus; the average size of the grains being about 1 millimetre. Four successive charges were made, the first three with pig iron, scrap, and ore concentrate, which was worked in the same manner as those with the Kungsgruvfa lump ore currently used; while in the fourth, pig iron and ore concentrate alone with some limestone, were used, the final additions of ferro-manganese and ferro-silicon being made in the usual way. The final charge consisted of 11·1 tons of pig iron, and 1·22 tons of ore concentrate, which quantity of metal should, according to previous experience, have yielded about 92 per cent. of its weight in ingots, or 10·212 tons as a maximum. The actual weight obtained was, however, 10·874 tons, showing an excess of 0·662 ton, recovered from the 1·212 tons of ore added, corresponding to a reduction of 57 out of the 72 units, or a utilisation of 75 per cent. of the iron contained in the ore. The time required for working this charge was about one-half more than when scrap was used; but Dr. Tholander considers that, with longer experience of the method, this might probably be reduced, and also that it would be possible to increase the amount of ore used from 11 to 15 per cent. of the weight of the pig iron.

The composition of the ingots was as follows:—

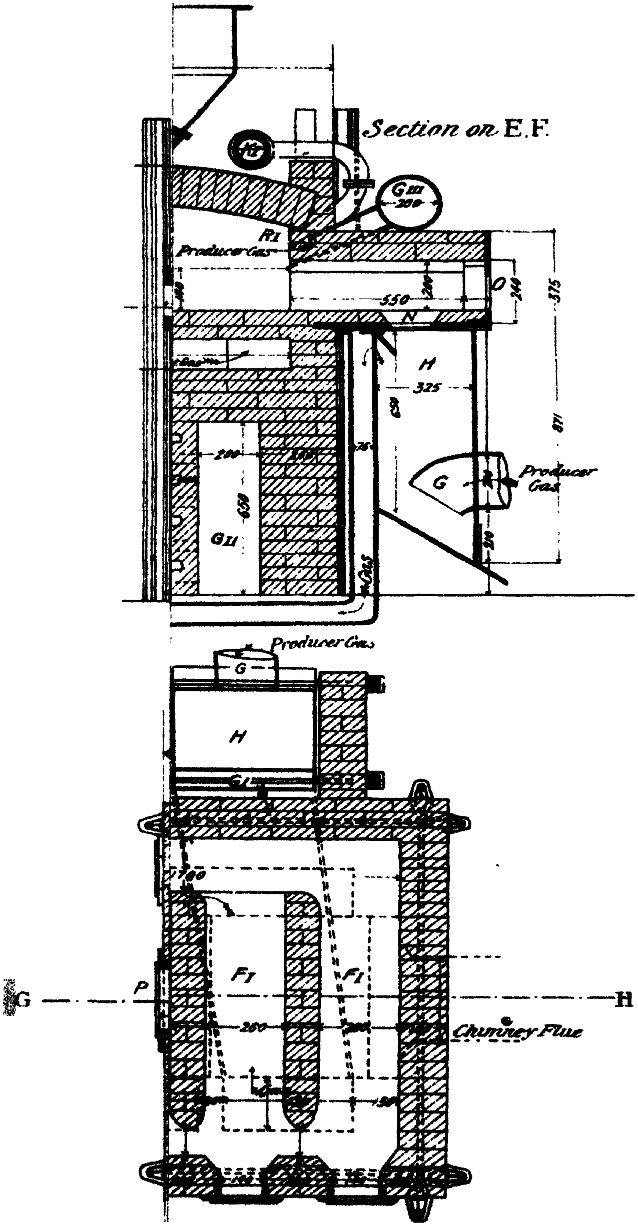
| | |
|---|---|
| Carbon . . . . . . . . . . . | 0·12 per cent. |
| Manganese . . . . . . . . . . | 0·33 ,, |
| Phosphorus . . . . . . . . . . | 0·027 ,, |
| Sulphur . . . . . . . . . . . | 0·003 ,, |

Another application, due to Mr. I. A. Brinell, is an improvement on Ellershausen's process of incorporating the ore with the pig metal at the moment of casting. An ingot mould is partly filled with fluid metal from a ladle, and when it is about to solidify, a quantity of small ore is thrown upon the surface, and this is repeated until the mould is full. From 12 to 15 per cent. of ore can be added without notably diminishing the cohesion of the ingots which are to be used instead of pig iron in the open-hearth furnace charge. Rich and heavy concentrates are admirably suited for this use.

## IV.—Direct Reduction of Pulverulent Ores.

As it is possible to obtain concentrated ore containing more than 70 per cent. of iron, and practically free from earthy waste, it seems to be an unnecessarily circuitous proceeding to convert it first into pig iron when soft iron or steel is required, such material being especially well suited for direct reduction to sponge iron capable of replacing scrap in the open-hearth furnace. For this purpose the author has designed the furnace represented in Plate I. This contains a heating chamber, D, in which the powdered ore supplied from the storage hopper, B, is brought up to a high temperature by the spent flame, and a reducing hearth, C, with a hopper, A, for supplying charcoal-dust. The heating is done, partly by producer- or water-gas, from an outside supply, and partly by the combustion of the carbon monoxide resulting from the reduction of the ore by charcoal. The substructure contains a system of recuperator pipes, and a capacious sheet-iron reservoir H is provided for cooling the reduced iron out of contact with the air, the general system of heating being as follows:—The gas coming from the producer by the tube G passes through H, in order to cool down the sponge reduced in the preceding charge, and then by GI and GII, and the recuperator EE into GIII, where it enters the reducing chamber by two rectangular nozzles close by the springing of the arch. The gas produced in the reduction chamber passes by the flue opening T into the vertical passage F, where it is burnt by air from the tuyere R, connected with the blast-pipe K, and the spent flame passing by the passages FI, FII, and FIII below the chamber D, and finally through the recuperator E to the chimney. The charge of ore from D is

**PLATE I.**


Section on E.F
Air
G III
200
R1
Producer Gas
140
200
550
O
240
375
N
H
325
650
871
G
Producer Gas
210
G II
200
650
75
Gas
Producer Gas
G
H
G1
760
F1
F1
G
P
H
280
280
Chimney Flue

pushed through the passage Q into the reducing chamber, and spread out upon the bed, where it may be subjected to a further heating if required, by burning the producer-gas under the arch by an air supply brought in through the tuyere R. The reduction can then be effected by gas or carbon alone, or by a combination of both methods, the charcoal being dropped from the hopper A and incorporated with the ore by rabbling through the working door at O. After final reduction with charcoal, the sponge iron appears as a granular aggregate of small coherent masses of iron. This is drawn out of the chamber and dropped through the passage N into the receiver H, where it is cooled in the gas current from the producer as previously stated. When cold, it is removed by the door at the bottom shown in the section EF. The reduced material, which is only very slowly changed by exposure to the atmosphere, consists of a mixture of iron and charcoal powder, which can be removed by an air blast or a magnetic separator. For use in the open-hearth furnace it may be packed into cast or sheet iron cases, or compacted by pressure into masses to take the place of scrap in the charge.

The PRESIDENT was sure that members were very thankful to the author of the paper and to Mr. Bauerman for the pains he had taken to put it so admirably before them. Before he invited discussion on the paper he would ask Mr. McNeill to read his paper.

# SOME FORMS OF MAGNETIC SEPARATORS, AND THEIR APPLICATION TO DIFFERENT ORES.

BY H. C. McNEILL Assoc. R.S.M.

THE first application of magnetism as an agent for the separation of a magnetic from non-magnetic substances was probably the permanent hand-magnet used in the machine-shop for separating iron or steel turnings, &c., from brass or gun-metal sweepings. Similarly foreign oats and grain are freed from bits of iron wire, pieces of cutter blades, nails, needles, &c. The railway companies and other large employers of horse labour have found it necessary to subject all the materials utilised for horse food, such as maize and oats, to rigorous mechanical and magnetic cleansing, for which purpose a permanently magnetised steel plate about 4 feet long, 6 inches wide, and ⅛-inch thick, with the long edges horizontal, is placed transversely, and inclined at an angle of about 35° to a continuous stream of grain fed from a hopper. An automatic scraper, in the form of a belt revolving round pulleys at each end of the magnet, and provided with a brush of leather, removes any accumulation every two minutes. This is pushed to the end of the magnet, and drops into a separate compartment; the grain which passes on is jigged on a three-bottomed perforated tray, by which means not only is the corn or maize separated, but the oats are freed from mixture of smaller seeds, bits of stone, and dust.

With the introduction and wider application of electro-magnetism, not only have machines been devised whereby naturally magnetic iron ores are freed from admixtures of other minerals, but by a preliminary roasting, *i.e.* the artificial production of magnetic oxide of iron, other ores may be rendered suitable for a magnetic separation treatment. Mr. R. E. Commans mentions* that Sella, in Piedmont, in 1855, was the first to use an electro-magnetic separator, but to free the magnets the current had to be broken; also that in 1881 Heberle, at the Friedrichssegen Mine on the Lahn, introduced a continuous current machine for separating blende from spathic iron ore after a preliminary roasting. In addition to the separator which bears his name, and which is dealt with in this paper, Heberle also designed that part of the dressing floors at the Gellivare Company's Works at Luleå, where the apatite, after being separated from the magnetic iron ore with which it occurs, has to be freed from a small percentage of hæmatite before being converted into soluble phosphate.

---

* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxvi. 1893, p. 63.

Other workers, both in Europe and America, including Weström, Ball and Norton, Chase, Conkling, Hoffman, Kessler, Buchanan, King, Edison, and Wetherill, have all designed machines suitable to treat certain classes of ore which have come under their particular observation, and have successfully dealt with the problems presented by local conditions and peculiarities.

In the summer of 1898 the author had the opportunity of seeing some of the principal magnetic concentration plants in Sweden, and the present paper is mainly confined to these. He is indebted to the various managers of works, engineers, and others for the information freely accorded in every case.

The endeavour has been to present an outline of the machines and ore treatment processes. The sketches are entirely diagrammatic, and have been prepared from the author's hand-sketches.

The machines will be described, in each case with the accessory ore treatment processes, in the following order:—

1. The Wenström machine.
2. The Monarch machine.
3. The Delvik-Gröndal machine.
4. The two types of Heberle machine.
5. The Wetherill machine.

## 1. The Wenström Machine.

This is probably the simplest, and, for the particular purposes which it is intended to fulfil, the most efficient separator at present in use. Unlike most other designs, it is capable of treating ore of fairly large size, and it is not necessary that the stuff treated should be previously dried; its chief use is in such cases where the magnetite iron ore contains inclusions of rock, or where, as in open-cast workings, portions of the containing walls of the ore body get mixed with the ore in blasting and like operations. As a general rule, it is found to be more economical to pass the whole of this material collected together over a Weström machine, after the "best" of a blast has been dealt with, than to attempt further hand selection in the quarry or underground. In addition there are other uses to which this separator may be put, such as the treatment of cupola residues and foundry loam and sand; also the recovery of cast-iron shot entangled in blast-furnace slag, &c., &c.

FIG. I.

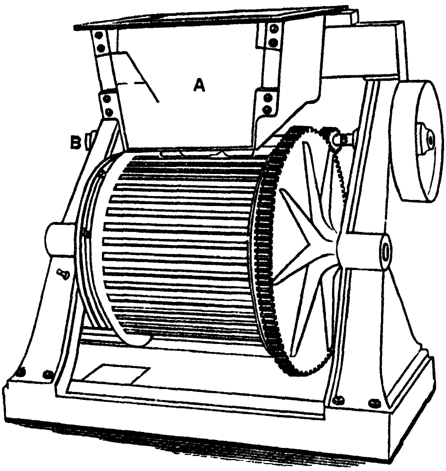


Fig. 1 gives a general view of this machine. The material to be treated is fed through a hopper A, and on to a jigging tray, which receives its motion from a cam arrangement placed on the shaft BB. This tray is inclined, and at each recoil a line of ore is left on the drum. Figs. 2 and 3 show part sections of the drum in directions at right angles to one another.

C is the armature barrel, consisting of a series of soft iron bars, each separated from the other by a bar of wood. D is a stationary field-magnet, placed eccentrically with regard to the armature barrel. Non-magnetic end plates, carefully fitted with "jointing," so as to be water-tight, bind up the whole into the form of a drum. The bars of soft iron are internally shaped, so that each successive bar becomes oppositely magnetised, a combination of greater power being thus exerted on a piece of ore large enough to bridge the distance between two adjacent bars.

FIG. 2.

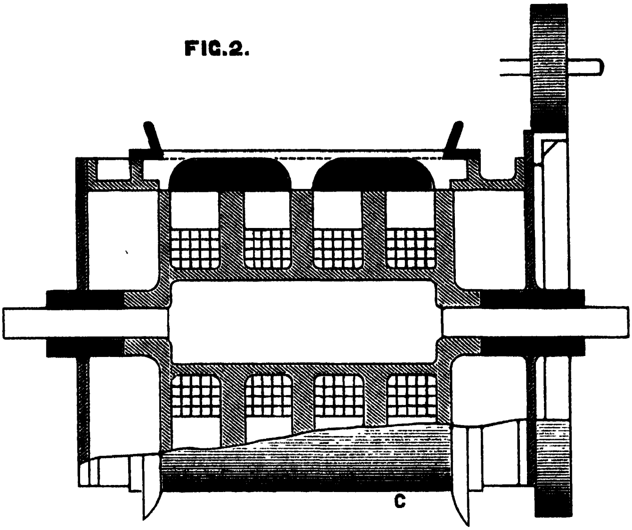
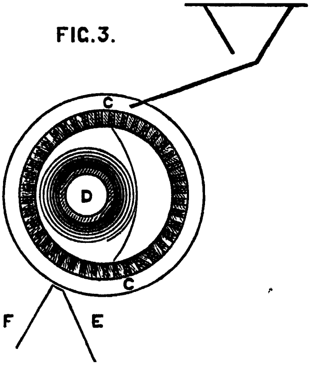


FIG. 3.



The magnetic portion of the ore adheres to and is carried round on the drum until beyond the influence of the magnetic field, when it drops away down a shoot at E, whilst the non-magnetic portion passes down in front of the drum into a shoot at F.

A machine with a drum of 2 feet 2½ inches diameter and 2 feet length, revolving at thirty revolutions per minute, will treat about five tons of mixed material per hour. Such a machine is capable of dealing with ore of any size up to pieces that will pass through a screen of 4-inch mesh, and requires a current of 15 ampères, the tension at the dynamo terminals being 110 volts. Although the machine may be and is used on ore which is quite wet, the greatest efficiency is obtained when the material to be treated is dry, and in some cases, as at Dannemora (Sweden), care is taken to treat only that ore which is fairly dry, without incurring the expense of artificial drying, whilst in other instances (Grängesberg and Grangen) the ore is treated directly after being washed, and whilst quite wet.

This separator requires but little care and attention when working, whilst the cost of maintenance is practically nil.

Generally the most efficient plants are also the simplest. The process usually consists of either a rough preliminary sizing by means of revolving or flat screens, with or without washing, followed by treatment on the separator, or the uncleaned ore may be passed on to the magnetic machine direct, and subsequently screened into different market sizes. At Dannemora the latter method is adopted, and I am indebted to Captain Hammershal for placing at my disposal the particulars given in the following short description of the plant used there.

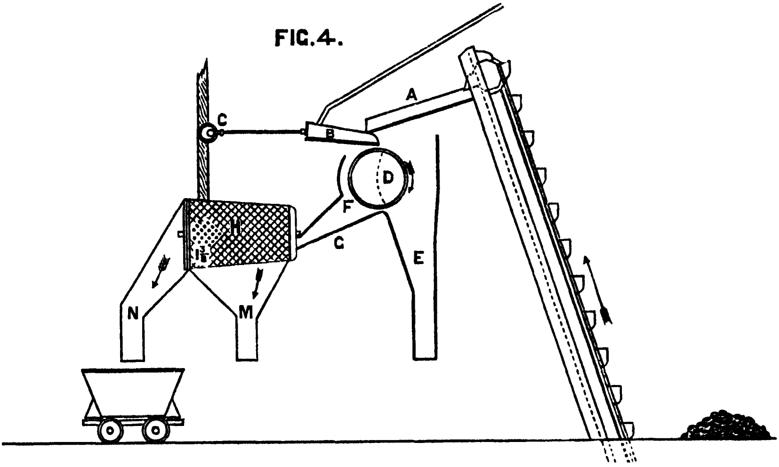
The ore on arrival at surface is first subjected to a rough hand selection on sorting-floors conveniently arranged near the shaft. Between 50 per cent. and 60 per cent. of the total quantity of ore raised is rich enough to be taken direct to the furnaces. The remainder, which is of any size up to 2 inches diameter, is trammed from the sorting-floors to the separation-plant, or to the ore heaps, for future treatment by the separator. Fig. 4 represents the plant in use.

By means of the elevator shown, the ore is lifted and dropped on to the inclined shoot A, and so on to the reciprocating table B, which delivers it to the Wenström separator, D.

The tray B receives its motion by means of the small eccentric C. The unmagnetic, and in this case worthless, portion falls at once down the shoot E. The magnetic portion is carried round on the drum of the separator in the manner already described, and passes down shoot G into the revolving trommel or screen H.

This trommel is of ½-inch steel plate, provided with ⅞-inch punched holes pitched 1⅝ inch apart, so that everything under ⅞ inch diameter passes through and down the shoot M, the stuff above ⅞ inch, which does not pass through the holes of the trommel, being delivered down the shoot N, two marketable products being thus obtained.

FIG.4.



An example where preliminary sizing and washing before separation is found to be advantageous is at Grängesberg (Sweden), and no doubt many of the members of this Institute will remember seeing the actual plant at work.

The mill is built at the foot of an embankment, so that the material to be treated is wheeled either in railway trucks or mine waggons directly into the top storey. During the winter, from obvious reasons, it is found impossible to run the mill; during this time large reserves of ore are accumulated. The railway trucks, when used, are so constructed that the whole sides are capable of being dropped, and rest horizontally on the top of grizzlies which extend from end to end of the truck. In Figs. 5 and 6 the truck is represented at A and the grizzlies at B. The ore is shovelled by four to six men out of the truck on both sides, and that which is too large to pass through is hand-picked into the waggons D by men and boys standing on the platforms shown. The grizzlies are made of bars of iron, rectangular in section, and placed 5 inches apart, so that all the material under that size falls down the shoots CC and on to a three-bottomed perforated recoil table E. If small stuff has to be treated, it is dumped

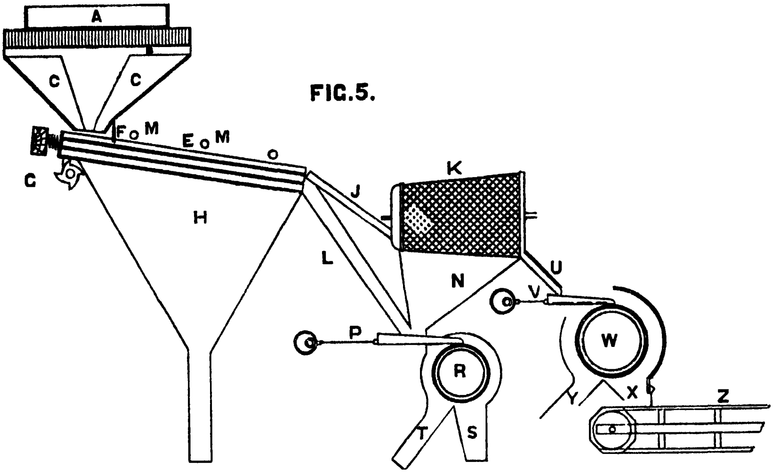


FIG.5.

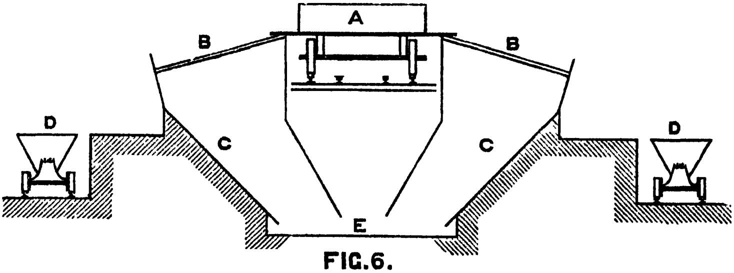


FIG.6.

directly down the central shoot (Fig. 6) from the mine waggons, which are run into the mill on the narrow-gauge rails shown and without being passed over the grizzlies. The three bottoms of the table are placed exactly above one another, and about 3½ to 4 inches apart, and are all actuated by means of the cam-shaft, cam, and springs. The top tray is provided with holes 1¼ inch diameter and 2 inches pitch; the middle tray has holes ¾ inch diameter, and the bottom one ¼ inch diameter. The ore is distributed in an even layer by means of the hinged iron plate F, assisted by the vibrations given to the table, by which means it is gradually worked down the tray, and at the same time is subjected to a thorough washing, the water for the latter purpose being supplied by the 3-inch perforated pipes MM. The result is that all fine particles of ore are washed through the three trays down the shoot H, and are carried off with the water by launders out of the mill, where boys are engaged in digging small channels, whereby the water very quickly drains away, leaving a coarse powder which is sufficiently rich to be marketable. The stuff under 1¼ inch and over ¾ inch diameter passes through the holes in the top tray, and is caught by the middle tray; that which is less than ¾ inch and more than ¼ inch diameter passes through the middle tray, and is caught by the third tray. Both sizes fall into the same shoot, L, and are treated on the smaller Wenström machine, R. The material between 1¼ inch and 5 inches, after being thoroughly washed, is delivered from the topmost tray into a shoot J, and then into a revolving trommel K, also provided with 1½-inch holes, and the ore which passes through these holes is taken by shoot N to join the products from the middle and lowest tray, and is treated by the separator R. Stuff between 1½ inches and 5 inches is delivered from the end of the trommel K on to the feed-plate of the larger separator W. The material which comes away from the "worthless" shoot X is deposited on to a slowly-moving broad metallic belt Z. Here any pieces of valuable ore are hand-picked off by boys and dropped into a shoot placed on either side of the belt; the worthless portion, being left on the belt, travels into a separate compartment. The use of the belt may be explained by the fact that the weight of some of the larger pieces of ore is greater than the magnetic force exerted by the machine, in which case they would fall off and get mixed with the worthless portion; also that it is more economical to adopt this method than hand-spalling and selecting the material to be treated according to more or less exact size. In addition, a lump of the stuff may be partly magnetite and partly unmagnetic, in which case, if the latter happened to come into contact with the drum first, it would not adhere.

Three commercial products are obtained :—

(1) Ore between 1½ inch and 5 inches diameter.
(2) Ore between 1½ inch and ¼ inch diameter.
(3) Ore anything up to ¼ inch diameter.

The Grängesberg plant was designed to meet the particular requirements at the mine; the ore contains a considerable amount of specular iron, which somewhat easily crumbles, also hæmatite, and differs from that of Dannemora, where the ore is compact and very hard and there is little or no tendency to crumble, hence probably the difference in the methods of treatment and the primary washing, in order to save and eliminate the fine material.

At both Dannemora and Grängesberg the uncleaned ore averages 38 per cent. to 42 per cent., and the concentrates 58 per cent. to 62 per cent. metallic iron.

The rejected portion of the material consists of quartz, pegmatite (from inclusions and veins running through the magnetite ore bodies), schistose material, &c.

In both the preceding cases the operations of sizing or screening the ore are carried out mechanically either immediately before or after separation, but it may happen that the deposit is so situated as to render it necessary that the ore should be brought down to a convenient mill-site, in which case the apparent disadvantages of position may be made use of in many ways. A case in point is at the Slotterberg Mine at Grangen. It appears that a considerable amount of work was done many years ago some 300 to 400 feet up the side of the hill, where large dumps were left by the old workers; in those days there were no magnetic separators, and only the very best picked ore was used; it is now found to be worth while to treat these old heaps. The stuff consists of anything between a powder and six inches diameter, and the whole of it, just as it comes to hand, is treated by screening, washing, sizing, &c., whilst on its way to the foot of the hill.

The first operation which the stuff undergoes is shown in Fig. 7 at A, where the ore is tipped on to a screen at that point, and is spread out by boys with rakes, the portion of the finer material which adheres to the larger pieces being sent through the screen. The latter, which has an area of one square yard, passes everything under 2½ inches diameter, the larger pieces remaining on the screen being hand-picked. After passing through the screen the ore falls down the wooden shoot, which is some 18 inches square in section and lined with iron plates, the whole roughly secured to trestles against the side of the hill, at about an angle of 45°. At B is a rectangular opening in the bottom of the shoot, 2 inches wide, which allows a quantity of the finer material to drop through, but which is skipped by larger pieces as they roll down. Arrived at the bottom of the shoot, the pieces of ore being thus fairly cleaned, fall on to another screen,

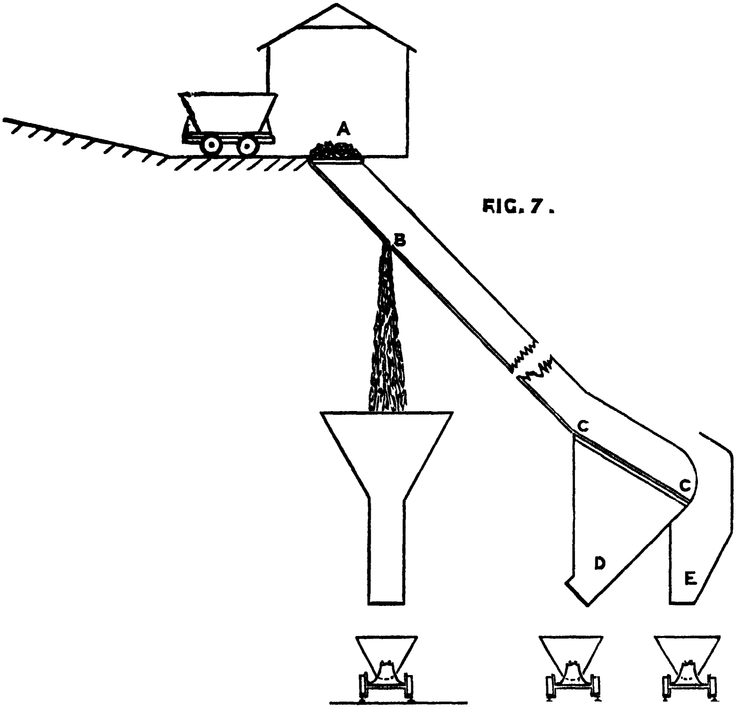


FIG. 7.

CC, with which the shoot terminates, where a further separation of the smaller material takes place. This screen is 10 feet in length, and the bars are placed longitudinally and ½ inch apart; the material under ½ inch diameter passes through and is caught in the shoot D, the finer stuff so eliminated, together with that which drops through at B, being dumped near at hand as worthless. The remainder, of size between 2½ inches and ½ inch, falls into shoot E; from this point it gravitates down an inclined tramway until it arrives at the top of another shoot or launder also placed against the side of the hill, and terminating in the separator plant (see Fig. 8).

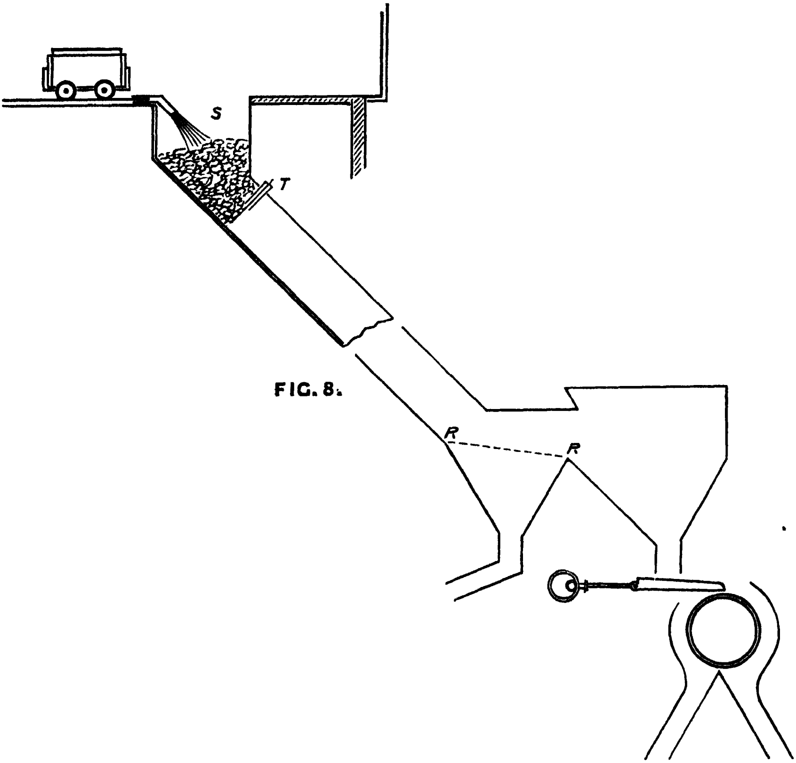
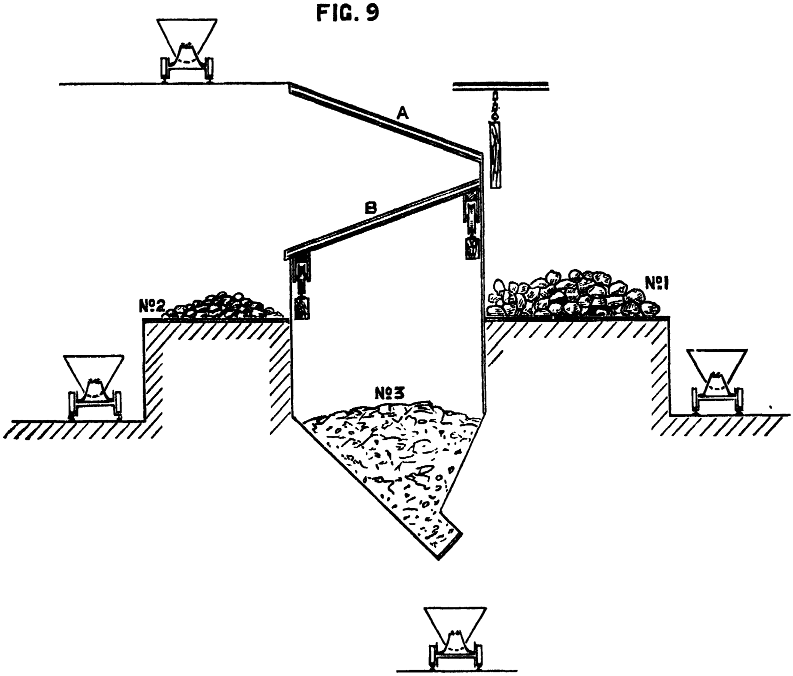


FIG. 8.

The product from shoot E is tipped from the waggon into a square chamber at the top of the launder, and is kept in place by a shutter or plate T, by means of which the feed of ore down the launder may be regulated, after being washed by water from the hose pipe shown. The height of the ore chamber S is 60 feet above the separator, and on its way down the material is well washed. At RR is a fine screen through which passes the finer material still left, together with the water, the residue of washed ore passing on to the Wenström machine.

FIG. 9



In addition to the old dumps mentioned, good ore has recently been discovered near the base of the hill, which is possibly a continuation of the deposit worked, as already stated, higher up. The ore thus obtained is first screened close to where it is mined. Fig. 9 is a sketch of the plant used for this purpose. A is an inclined screen made of old railway metals with an effective opening of 5 inches between each ; pieces above this size roll off the screen and form No. 1. Pieces under 5 inches pass through and are caught on screen B, also made of old rails, but placed 2½ inches apart, so that the material of size between 5 inches and 2½ inches falls to the sorting floor and forms No. 2. The ore under 2½ inches that passes through screen B forming No. 3.

No. 1 is hand-spalled, selected, and divided into
  (*a*) Almost pure magnetite.
  (*b*) Material containing 60 per cent. to 70 per cent. magnetite.
  (*c*) Gangue with 12 per cent. to 15 per cent. magnetite.
 (*a*) and (*b*) are sent direct to the furnace.
 (*c*) is dumped as worthless.
No. 2 is similarly treated.
No. 3 after a further screening is passed on to the separator.

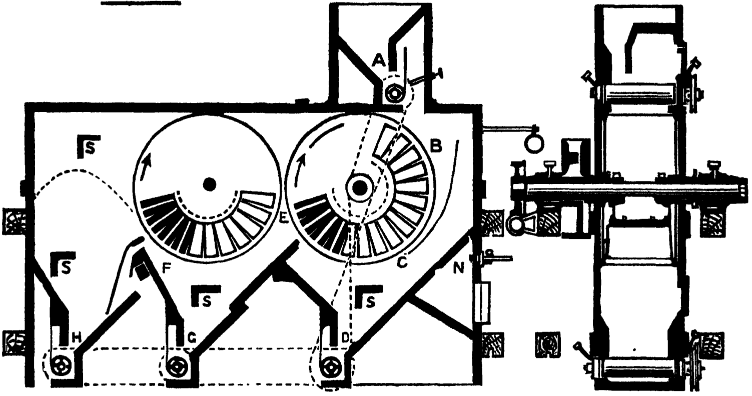
The top screen may be extended to any length according to the amount of ore to be treated. The under screen B is usually a short piece mounted, as shown in Fig. 9, on wheels, so that it may be moved under any part of the upper screen that it may be convenient to use. It is also a good plan to divide up the shed into compartments, so that when sufficient ore has been put through to be easily "looked over" by one man, the operation may go forward in another compartment; by this means also the workmen on the lower platform are protected from the falling ore.

### 2. The Monarch Separator.

The Monarch separator may be regarded as a Wenström with the single drum duplicated; it is, however, of a rather more delicate construction, and is a modification of and improvement on the original Ball and Norton machine, a class which includes the most successful machines of the eccentrically placed internal electro-magnet and the revolving drum pattern. Fig. 10 shows a sectional elevation of this separator. It is necessary that the ore treated should be quite dry, and in both cases where the author was enabled to see the machine at work in Sweden the best results have been obtained upon material crushed to pass through a one-millimetre screen.

The ore of the size mentioned after drying is fed in an even stream into the machine by means of the roller at A, the feed being capable of adjustment as shown. The mineral falls on the revolving drum B, which moves over the fixed electro-magnets, all the material being compelled to pass close to the drum by means of the bent shield BC. Having passed the point C, the non-magnetic portion or tailings fall into compartment D, and are fed out at that point by a similar roller. At or near the point E the particles hop across to the next drum in consequence of a stronger current being employed in drum No. 2, and are possibly helped by an induced current of air caused by the superior velocity of this second drum, the relative speeds being as 6 : 1. Those particles containing a little magnetite are whirled off drum No. 2 at about the point F, the centrifugal force being the stronger force of the two, and drop into the compartment G, constituting "middles" or "middlings;" the wholly magnetic particles are whirled off drum No. 2 at about the end of the electro-magnets, and are flung against the end of the machine, and are fed out at H.

FIG. 10



The "middles" may be re-crushed and re-treated, if necessary. A combination of three such machines, where the middles from two of them are passed through a third, is said to be capable of treating 200 tons of uncleaned ore per day of twenty-four hours.

One of the later improvements on this separator is the introduction of drums made of German silver, which has been found to increase the efficiency of the machine.

This form of machine, when used after a careful preliminary treatment, such as drying, crushing, screening, &c., is applicable to two classes of ore:—

(1) Those in which magnetite is more or less intimately associated with worthless material.
(2) And those in which the magnetic portion is of secondary importance.

To both of these cases the machine is successfully applied.

The extensive plant seen by some of the members of this Institute whilst at Luleå, in the north of Sweden, last summer, may be taken as a case coming under the second of these conditions, and which may be briefly described as follows:—

The ore which is put through the mill assays from 0·01 per cent. to 3 per cent. phosphorus, and is correspondingly low in iron, the phosphorus occurring in the form of apatite. Only the ore richest in the latter mineral, and hand-selected on this account, is put through the mill.

It is first passed through a Blake crusher and then through a single pair of Swenson rolls, the ore being thus reduced so as to pass through a ½-inch mesh screen. This product is then thoroughly dried by passing it through the revolving cylinder AB, fig. 11. This cylinder is 48 feet in length and 4 feet 8 inches diameter; it is inclined 1 in 18, and rotates once every five seconds. The ore from the hopper C is by means of the feed-plates at D passed in a constant stream into the cylinder, meeting the heated gases, &c., coming from the coal-fire at E. Having arrived at B, the ore, which is now quite dry and hot, falls down shoot G, being divided at that point into two streams (Fig. 11*a*), in order to miss the uptake from the fireplace E. At H is a revolving drum, and at K are placed an adjustable baffle-plate and a vibrating feed-tray, which not only act as a safety catch to prevent any object, such as a hammer-head, getting into the rolls, but also regulates the feed of ore, so that the rolls L have just sufficient ore to deal with, and do not get clogged up. After passing these rolls the ore enters the circular screen M. This screen is of $\frac{1}{16}$th inch thick steel plate with oblong holes, the details of which are given in the sketch (Fig. 11*b*).

A certain proportion of the ore, about 20 per cent. of the whole, which finds its way, or is small enough to pass through M, drops right down to the bottom chamber N, whilst the rest passes out of the screen, and is fed into the double rolls R, and after that passes into a second and similar screen M$^1$. The ore fine enough to pass through this second screen joins that which has already passed through the upper trommel M, whilst that which is still

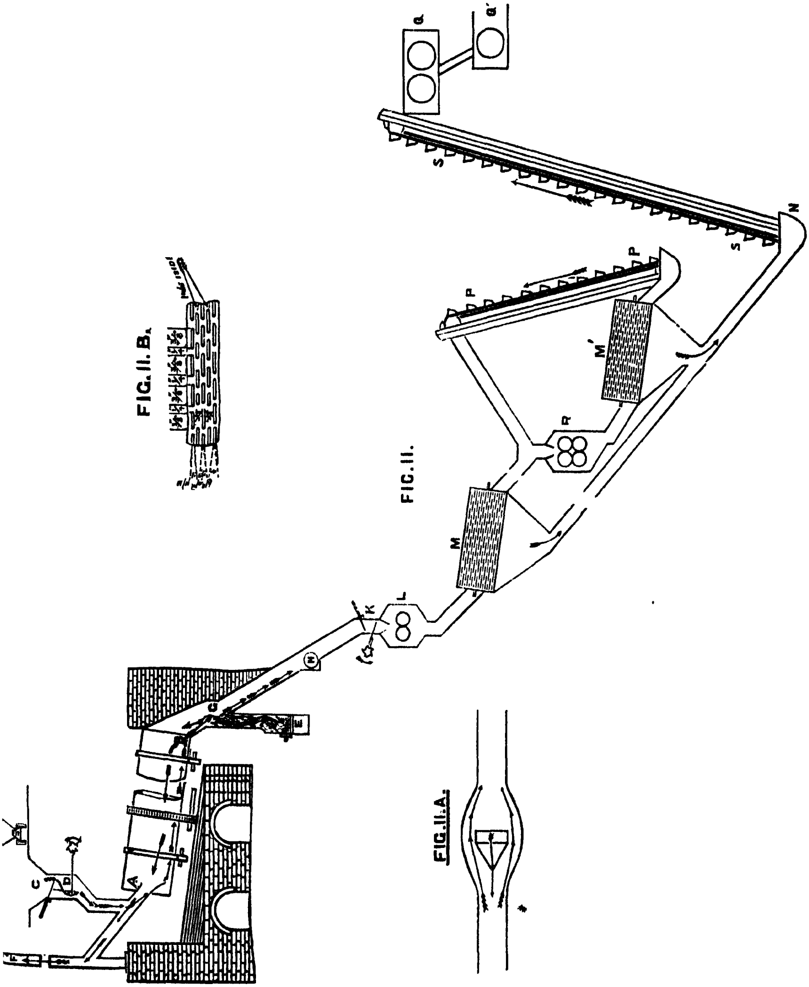


FIG. II.

FIG. II. B.

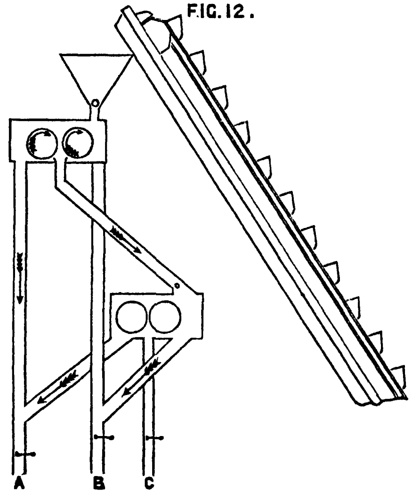
FIG. II. A.

too large is returned to the double rolls R by means of the elevator PP, and is recrushed. Assuming the chamber N to contain nothing but ore one milimetre diameter, this is then transferred to a Monarch separator Q by the elevator SS, the "middlings" from which pass down, and are sent through a second separator $Q^1$.

The plant is in duplicate, *i.e.* Fig. 11 represents just one-half of the mill, each half working independently of the other half, and there are therefore four separators at work, two to each half.

The arrangement made for joining the like products from two separators is shown in Fig. 12, where the two concentrates join together and are collected at A, and the tailings similarly at B, whilst the "middles" from the top machine are taken to the lower separator, and the "middles" from which again collected at C.

FIG. 12.



All the screens, rolls, separators, elevators, shoots, &c., are boxed in with wood, and the dust from them, by means of mains and exhaust fans, drawn to a separate house, allowed to settle, and removed when necessary for further treatment.

It might be of interest to note that the tailings, consisting of apatite, with a very small proportion of magnetite and some hæmatite, constitutes the most valuable product delivered from the separators.

This then goes forward and receives further treatment for the separation of the small residual portions of iron compounds, and the finished phosphate of lime is finally converted into the soluble phosphate of soda by the Wiborgh process.

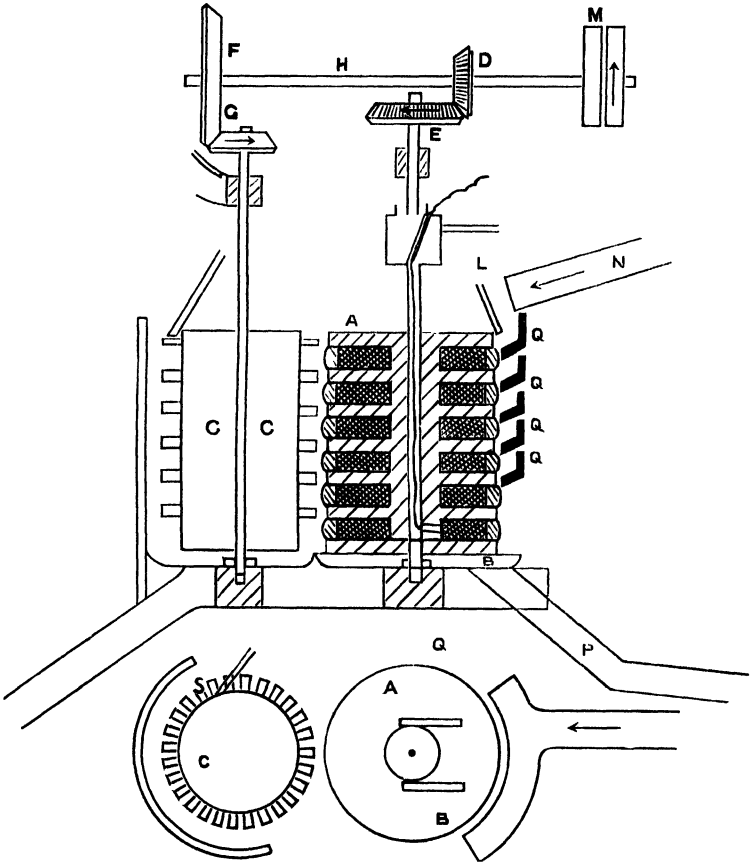
A similar plant to the one just described is also used, as already mentioned, where magnetite has to be separated from other and worthless minerals. In this case, the only point that it is necessary to draw attention to is that the ore itself, in the absence of any appreciable quantity of apatite, may be harder, and the initial crushing more difficult to accomplish. At Herräng a No. 5 Gates crusher is employed for this purpose.

### 3. THE DELLVIK-GRÖNDAL SEPARATOR.

This machine is designed to treat those ores in which the magnetite exists in a state of intimate admixture with other and in general worthless minerals. At present it is at work, and is successfully treating low-grade magnetite ores. The preparation that the ore has to undergo before it is passed to this form of separator will be described when dealing with a plant now working at Baggå, in Sweden. For present purposes, the material may be described as a slime. Fig. 13 shows a sectional elevation and part plan of the machine. AB is of cast iron, and consists of a series of rings. In the spaces between each of two is placed the copper wire conveying an electric current. This drum is rotated by means of the bevel gearing DE and the pulley-shaft H.

CC is a solid drum of wood caused to revolve three times faster than AB by means of the gearing shown at FG and is studded with soft wrought iron bolts or pegs, each ring of which revolves exactly opposite to the rings on AB. It will be noted, as indicated by the arrows, that AB revolves from right to left in front, and CC from left to right in front. The slime is carried to the machine by means of the launder N, which terminates in the circular launders QQQQ, which enclose the drum AB for about one-third of its circumference, as seen in plan, and offer a larger area of the slime to be acted upon. Further water is supplied by the pipe L. The magnetite particles thus brought under magnetic influence attach themselves to the rings on AB, and are carried round. Those particles which escape the first ring are caught lower down, and so on, each successive ring being more strongly magnetic than the one above. The unmagnetic portion of the ore, being unattracted, is washed down and into

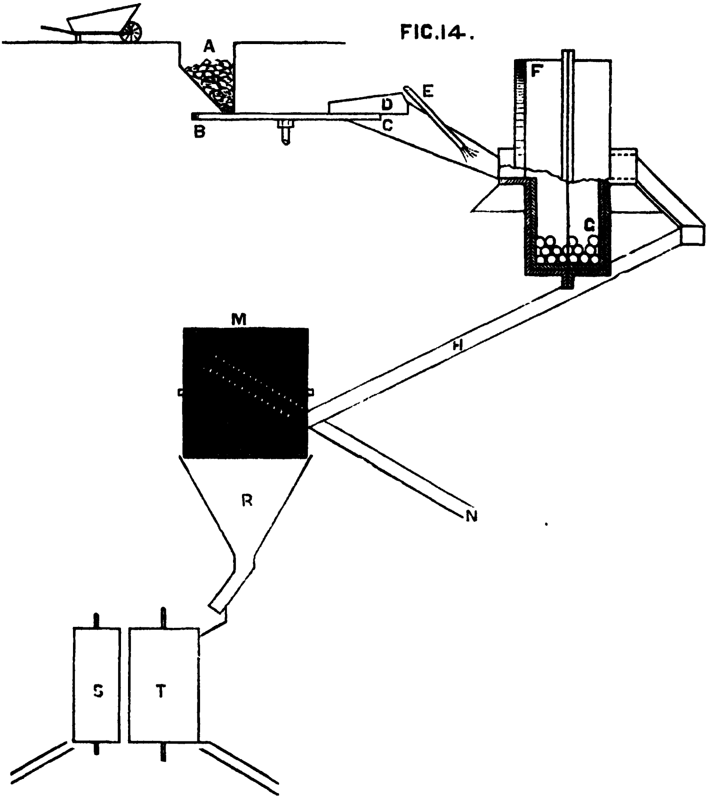
FIG. 13.



launder P, together with the excess water. As each peg of the drum CC is successively presented to the rings of the drum AB, magnetism is induced therein, and the magnetite hops over and forms in tufts on each peg, and is thus carried out of the magnetic field, where most drops away, and the rest is washed off by a strong jet of water from the pipe shown, this separated magnetite being run by the launder into settling pits, from which it is dug out.

The copper wires conveying the electric current are protected by carefully-fitted brass rings and special jointing.

FIG. 14.



The necessary fine crushing before treatment in the separator is accomplished by means of a ball-mill. Fig. 14 is an attempt to show a small plant designed for the purpose of treating a low-grade ore, in which it is necessary that crushing should be carried to such a point that all the material shall pass through a 12-mesh screen. The first coarse crushing is done by means of a Blake machine, which reduces all the ore to about walnut size, after which it is passed through a ball-mill, a feature of which is an ingenious arrangement by which a regular feed of ore is supplied to the mill. BC is a horizontal circular revolving plate, the height of which can be adjusted so that the distance between the bottom of the hopper A and the moving plate BC can be so regulated that just sufficient ore is allowed to drop through and is carried round on the plate. D is a fixed guide-plate, under which the plate BC revolves, and the ore, in coming up against it, is slowly pushed off and into the shoot leading to the ball-mill FG. This is of cast iron, lined internally with chilled plates, the latter removable, and is caused to rotate forty times per minute upon hollow trunnions, through which ore is fed in on one side and out on the other, water being supplied by pipe E. Coarse slime is thus produced, and passes out with the excess water down an open launder H, and into a revolving screen M of wire gauze, with 140 holes to the square inch. The stuff already fine enough to pass through drops into the shoot R, and is treated in the Dellvik-Gröndal separator ST, whilst that not sufficiently fine is carried up on the gauze inside and drops from the top on to the enlarged end of a launder N, and is returned to the mill by a small pump.

Professor G. Nordenström, in a paper read before this Institute at the Stockholm meeting last August, mentions the fact "that the Dellvik-Gröndal separator has been advantageously used at Pitkaranta, in Russian Finland, since 1894, for concentrating poor iron ores."

### 4. THE HEBERLE SEPARATOR.

There are two distinct types of machine, each of which is shown in separate figures.

Fig. 15 is a type designed for the separation and concentration of low-grade magnetic ores only.

Fig. 16 is designed for the treatment of galena blende ores when occurring with magnetic oxide of iron, also the separation of roasted spathic iron and blende, &c., or in the treatment, which will be described below, of a complex ore consisting of galena blende, magnetic oxide, pyrrhotine, and quartz.

In Fig. 15, the ore to be treated, after reduction to size of about 30-mesh, is fed in at A with water. BB is a continuous gutta-percha belt travelling round the pulleys CC and over the fixed electro-magnets placed in the casing shown, the whole machine being enclosed in a wooden box, which is kept full of

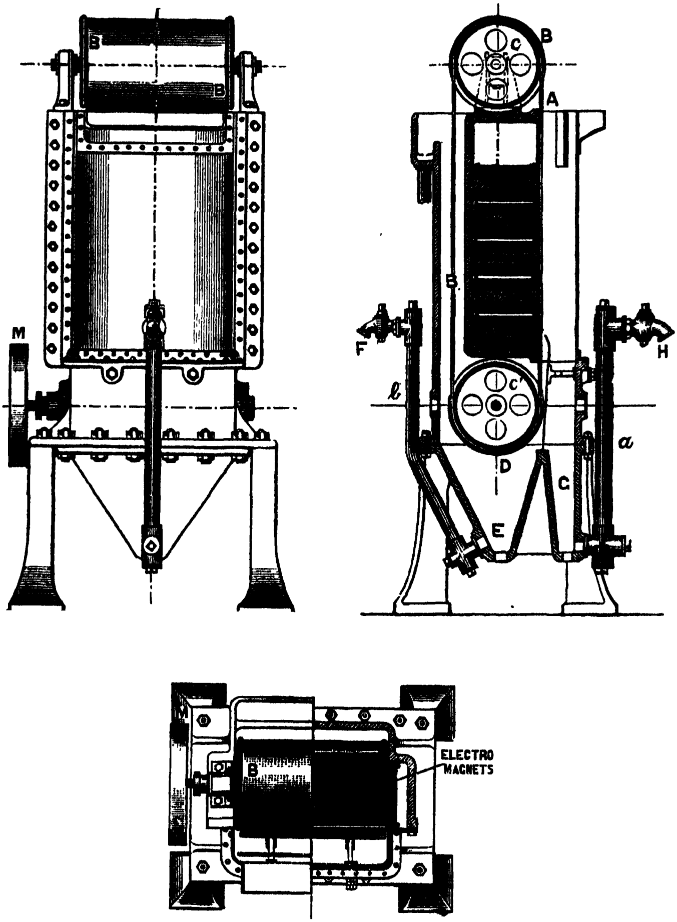


FIG. 15.

water to a height a little above the highest of the magnets. The magnetic portion of the ore attaches itself to the belt, and is carried down with it until, arriving at D and out of the field, falls away into E, and is withdrawn through F. The worthless portion falls into G, and is withdrawn through pipe H. The width of the belt may be from 1 foot 8 inches to 2 feet 6 inches, and a machine of the latter size is capable of treating thirty-five tons

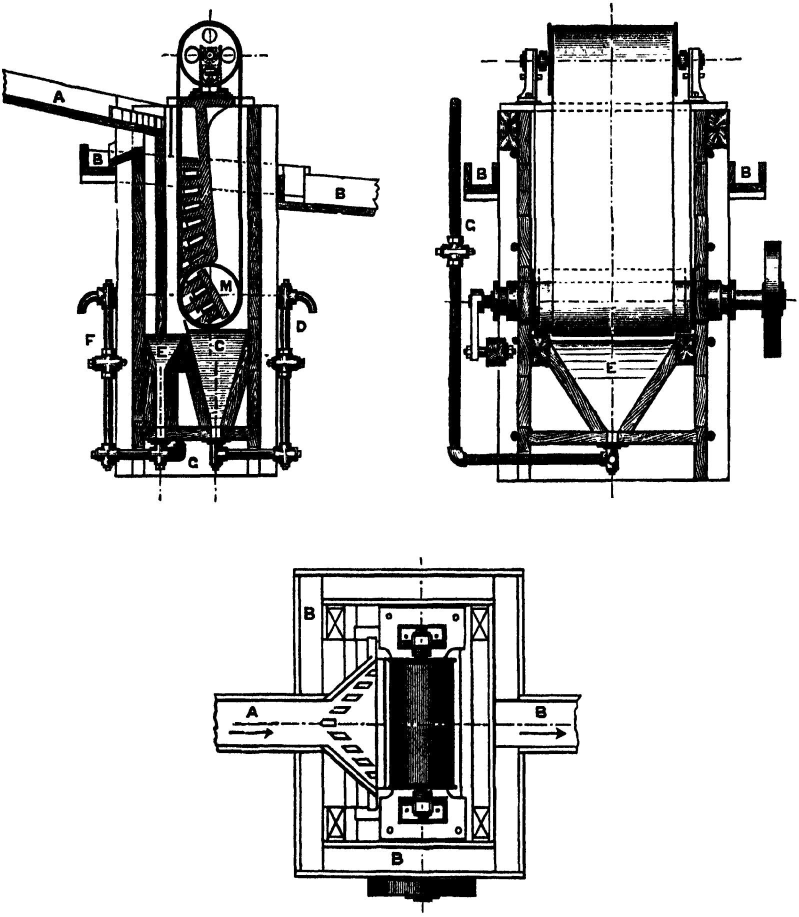


FIG. 16.

of crude ore per day. These separators may with advantage be used in series where a favourable percentage of the magnetic iron might be obtained from the ore by a primary crushing of from 6 to 3 millimetres and treatment in separator No. 1, Fig. 17, the rejected portion being further reduced in size to say 3 to 2 millimetres, and treated in No. 2 separator, and so on with intermediate crushing between two such separators.

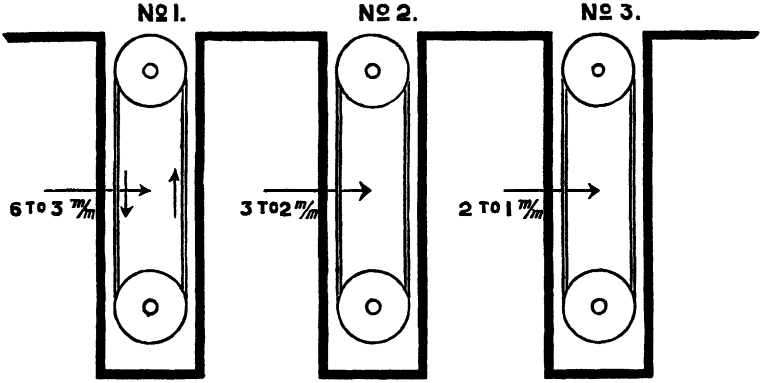


FIG. 17.

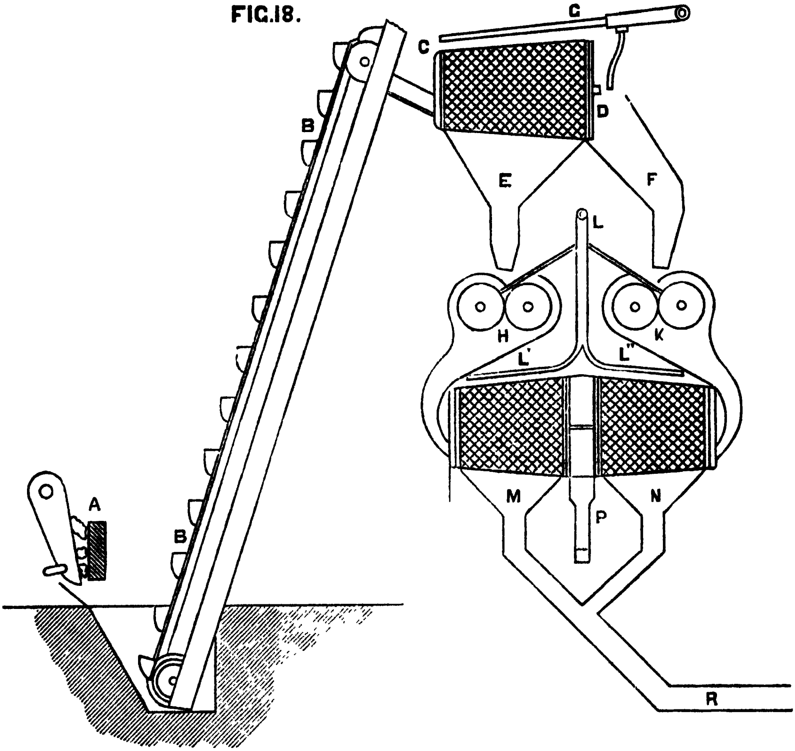
At Saxburget, in Sweden, where, by the kindness of Mr. Wenström, I was permitted to see their mill, they were treating an ore consisting of approximately:—

| | Per Cent. |
|---|---|
| Lead | 11 |
| Zinc | 22 |
| Magnetic oxide | 14 |
| Pyrrhotine (magnetic pyrites), $Fe_6S_7$ | 2 to 5 |
| Silica | 15 to 20 |

which is obtained from the adjacent Långfallsgrufvan mine.

The ore is first hand-cobbed and picked over to roughly pieces of 6 inch diameter. It is then passed on a Blake breaker A, Fig. 18, which reduces it to the size of about $\frac{3}{4}$ inch diameter. It is then lifted into the trommel CD, provided with $\frac{5}{8}$-inch holes, by means of which the material less than $\frac{5}{8}$ inch passes through and goes on the fine rolls H, together with water supplied by the pipe G. Material larger than $\frac{5}{8}$ inch, or between $\frac{5}{8}$ inch and $\frac{3}{4}$ inch passes down F to the coarse rolls K; also with water supplied by the pipe shown. From these rolls the crushed ore passes to further trommels, M and N, provided with holes of about $\frac{1}{32}$ inch. The stuff already small enough passes down in the shape of a slime by launder R, direct to a Heberle separator of type shown in Fig. 16, and anything above $\frac{1}{32}$ inch is returned from P to the fine rolls H and re-crushed. The ore now consists of a slime containing all the minerals mentioned above, and in this state is run into the separator, Fig. 16, at A; the magnetic portion is carried down on the belt, and deposited into chamber C, and withdrawn by a pump through D. The coarser portion of the remainder of the mixture accumulates in E, and is withdrawn through the pipe F, the outer case of the separator being kept full of water up to launder B by means of the water-pipe G, the finer portions of mixture, consisting mostly of the blende and silica, together with about 3 per cent. magnetite, in a state of

FIG.18.

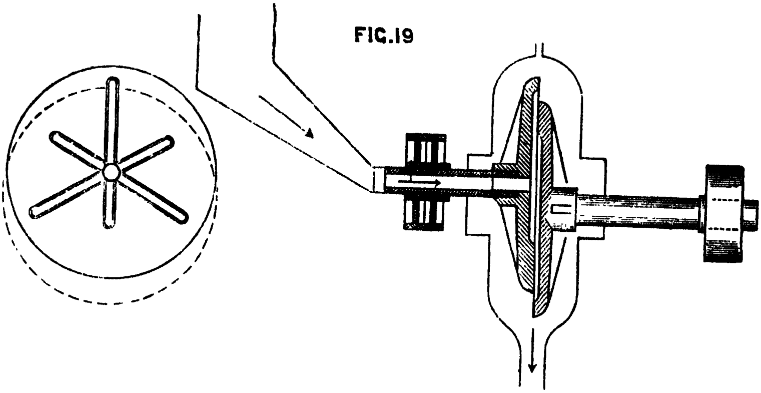


suspension, are carried away by the overflow B to settling pits for subsequent re-treatment as fine slimes.

The magnetite, after withdrawal from C, here disappears from the process, as although it contains a little zinc and lead, it is found unprofitable to treat it further.

The material which collects in chamber E then goes forward to a four-compartment jig, whereby the coarser galena becomes a separated and sized product, and the other products are reground in a special form of mill designed by Heberle and shown in Fig. 19, and consisting of two fluted plates rotating concentrically against each other, after which as much as possible of the other minerals are separated by means of pointed boxes, continuous revolving buddles, and Rittinger side recoil tables, &c., &c.

FIG.19



## 5. The Wetherill Machine.

This machine has been designed to treat the ores met with at the Franklin Mines, New Jersey, United States, which contain Franklinite (the chief iron and manganese bearing mineral) intimately mixed with zinc oxide and Willemite (zinc silicate) in a limestone matrix. The problem was to utilise the natural and slightly magnetic properties of the Franklinite, separate it from the admixture of the other ores, and so concentrate the zinc minerals sufficiently high to admit of their reduction in the

Belgian spelter furnaces. The original treatment was to roast the ore with anthracite, so increasing the magnetic properties of the Franklinite, and treat the roasted product on a Wenström separator. Mr. J. P. Wetherill found on experiment that, by concentrating his magnetic field, the Franklinite, described by Dana as slightly magnetic, could be separated without preliminary roasting.

There are two types of Wetherill separator for treatment of ores of different grades.

Messrs. H. A. J. Wilkins and B. H. C. Nitze, in a paper read before the American Institute of Mining Engineers at the Pittsburgh meeting, February 1896, gave sketches and some details of these machines, from which it appears that the crushed and dry ore is subjected to the selective action of a highly concentrated magnetic field.

The author has had no experience with this type of machine, but there is little doubt that, in the treatment of complex ores, many of which consist of minerals described as "feebly" or "slightly" magnetic, considerable possibilities are opened up in the direction originated by Wetherill.

Messrs. Wilkins and Nitze mention "That amongst the minerals which have been found susceptible of attraction by the condensed magnetic power of these machines may be mentioned red and brown hæmatite, siderite, chromite, menaccamite, rutile, Franklinite, pyrolusite, &c.; in fact, almost all minerals containing iron or manganese, or both, also salts of iron, manganese, and chromium; and with the introduction of still higher magnetic powers, it is hoped that even iron pyrites will come within the scope of successful separation treatment."

In conclusion, attention may be drawn to the increasing utilisation of magnetic iron ore, not only in this country, but to a still greater extent on the Continent, and to the growing importance of magnetic concentration as a branch of technical industry. There is undoubtedly a large field open both to the inventor and for the remunerative employment of capital, and the author hopes that these notes, as describing more particularly the Swedish practice, may not have been without interest.

## *DISCUSSION.*

Mr. James Riley, Vice-President, said he did not rise to criticise the interesting paper of Professor Wiborgh, but in order to mention a method he had devised of using finely divided iron ore. This subject had been frequently under his consideration for a long time past. In the end he arrived at his conclusion by studying the subject from two points of view: first, as regarded the use of the ores themselves; second, as regarded a costly and troublesome by-product or waste product of the open-hearth steel manufacture. In the course of last year there were probably made in this country 500,000 tons of steel-melting furnace slag which probably contained 100,000 tons of iron, worth to-day, if it were in the form of pig iron, £350,000, or, if they valued it as an iron ore at 4d. per unit of iron, £160,000. It was evident also that if this iron could be recovered by an economical method—if, for instance, the slag could be sent direct to the blast-furnace—the steelworks would be saved the trouble and expense of dealing with this immense waste product. He was aware that this slag had been used, and was now used, in the blast-furnace in the manufacture of special products, but the quantity so used was an infinitesimal proportion of the whole. He was also aware that in some cases this slag was used in ordinary blast-furnace practice—he had so used it himself—but he was very doubtful as to the economical results of smelting a slag with only 20 per cent. of iron. If the percentage of iron could be increased up to between 40 and 50 per cent. of iron, then it would have a real value, and from being a nuisance and trouble would become a desirable commodity. It occurred to him some time ago that in these finely divided iron ores they had the means at hand for so enriching this slag. If they could at the time when they were casting a charge of steel, and when the intensely hot and fluid slag was overflowing from the furnace or ladle, mix with it a sufficient quantity of these rich small ores, they would accomplish both objects they had in view; they would then have a vehicle for conveying the powdery ores into the furnace in the solid state, and they would have converted the slag into a useful ore of iron, free from moisture, and in a condition to be readily and easily smelted. In fact, with proper arrangements for the purpose, they might charge it into the blast-furnace while still in a heated condition. That it was possible to make this agglomeration of slag and ore—conglomerate they called it —had been proved in practice. They had made and used considerable quantities of it, but a little consideration would show that there must be special arrangements made before this practice could become part of the daily routine of a steel-melting shop. That it was worth doing must be apparent; that it would be done in many cases he fully believed. He would only add that his present object was to make them acquainted with his method of dealing with these ores, by which method he also accomplished an equally desirable object, namely, the use of melting furnace slag, with a saving of many thousands of pounds yearly as one of its results.

Mr. G. J. **Snelus**, Vice-President, said the treatment of finely powdered ores was one which had interested him more or less all his lifetime. His first patent was taken out in 1868, by Mr. Menelaus, for directly reducing powdered iron ore into the state of metallic iron. He had, after a very long series of experiments, ascertained that if they powdered the iron ore into a very fine state of division, the process of separating the oxygen was a very simple and a very rapid one; and, in fact, he showed the late Mr. T. S. Blair, when he was at Dowlais carrying out the Ellerhausen process, that in order to get metallic iron, it was only necessary to expose finely divided ores to proper reducing conditions for the space of a few minutes. That fact impressed itself very much on his own mind, and he considered for some time in what way this fine ore could be dealt with. He finally came to the conclusion that it must be dealt with in a continuous process and by mechanical means, and that the furnace which had been lately introduced into the copper smelting works, viz., the Gerstenhöfer furnace, lent itself to this process, by making it a reducing instead of an oxidising furnace. He submitted his views to Mr. Menelaus, then manager of Dowlais, and he kindly took out a patent for directly producing iron from finely powdered ore. At the meeting of the Iron and Steel Institute which followed at Merthyr, he was introduced to Mr. Henderson (through Mr. Pattinson of Newcastle), and he then discovered that Mr. Henderson had taken out a similar patent one year before, and that he had passed it over to the Tharsis Company. It turned out that the Tharsis Company never used the process, and allowed the patent to lapse. But Mr. Henderson told him that he was perfectly confident that it was a practical process; and knowing Mr. Henderson's skill as the originator of the process for making ferro-manganese, he was sure they would consider that his opinion was of some value. He had recently had occasion to revert to this after thirty years of interval, and he was now engaged in considering whether this process could not still be used for the first portion of the process of iron-making. He believed that it was possible, and that there was a very large field for producing iron from finely powdered material, which, as they had been told, could be obtained of very rich quality. There were very numerous deposits where they had to deal with these fine ores. He was very pleased that this paper had been read. He had hoped to hear that some results had been obtained from this furnace which had been designed by Professor Wiborgh, but they were told that up to the present time no actual work had been done with it. Therefore, of course, it was still in the theoretical stage. He thought that dealing with finely divided ores was a very important subject, and the process most likely to effect success would be one in which the material was dealt with mechanically and continuously, and not by hand-labour. He knew no other form of furnace than the Gerstenhöfer furnace, which he might describe as a tall rectangular chamber filled with triangular bars of fireclay running from side to side, and spaced so that any fine material filled in from the top dropped on these bars, first to one side and then to another, and finally found its way to the bottom of the chamber. That was very successfully used for calcining iron pyrites. He saw it in use at Swansea. Their late lamented friend, Mr. Thielen, was then in charge, and very kindly on that occasion explained the whole thing to him. They talked the matter over, and Mr. Thielen quite agreed with him that the application of that furnace to the direct reduction of iron, by arranging that it was heated with a strongly reducing atmosphere was quite a practical possibility. He thought, therefore, there was an opening for dealing with finely divided ores in this direction, and he hoped later on to make some practical suggestions on the subject.

Sir LOWTHIAN BELL, Bart., Past-President, said that during his now not very short life he had met with two classes of inventors who advocated the adoption of what he called the direct process of producing malleable iron. The first of these were those who promised that in time they would succeed, and as a type of these he hoped he should be pardoned for classifying Mr. Snelus. The others were composed of those who had already achieved success, and he would give them two names in connection with that type. One was his lamented friend Sir William Siemens, and the other, if he remembered rightly, was the very Mr. Blair just now mentioned by Mr. Snelus. He went to the works of both these gentlemen. He went first to the works of Mr. Blair, who had erected a considerable establishment of the kind near the city of Pittsburg, and when he came back he ventured upon the hazardous step of questioning the accuracy of Mr. Blair's observations. Mr. Blair was somewhat displeased at the opinion he (Sir Lowthian) expressed, but, nevertheless, within a year or two of that time these works were dismantled. He afterwards visited the works of Sir William Siemens, and that which he was promised he should see he never did see; and he thought the soundness of his views might be assumed to be corroborated by the fact that Sir William's furnaces were also discontinued. What was the problem that they were called upon to solve? Supposing they took an ore containing on an average 50 per cent. of pure iron, that meant that they had to submit to all the operations described in the paper, and although those operations appeared simple, they would find in the long-run that it would become a very costly process from the expense of having to deal with two tons of ore for every ton of iron that they obtained. If steel was the object ultimately aimed at, he (Sir Lowthian Bell) thought it would be found less expensive to adopt a treatment to separate the impurities taken up by the iron in the blast-furnace from one ton of pig iron, than to escape such contamination by any form of direct process hitherto described.

Mr. J. E. Stead, Member of Council, said the two papers were of a most important character. The magnetic separation of ores from their matrix was one of the questions which they had to consider very seriously at the present time. Ores were getting scarcer and scarcer every day, and therefore they must now look to fields or beds of iron ore which in the past they discarded. There were many practical points raised in the papers with reference to the use of the finely divided magnetic oxide in the blast-furnaces and in the open-hearth. About twenty-five years ago he had had some experience in working the very fine magnetic sand from Marbella, which was almost identical in character with the magnetically separated sand. It had about 55 per cent. of iron, and was almost like the sand on the sea-shore. It came by mistake to the Witton Park Iron Works, near to Bishop Auckland, in the Durham district. The order was given to put 25 per cent. of this on to the furnace charge, with the most disastrous result. The furnace was gobbed up in twenty-four hours, and it took a week to get it open again. The sand ran right down to the bosh, and accumulated there. It formed a nasty scaffold, and they had an enormous amount of trouble to get the furnace into working order again. After that they only put on about 1 per cent. With reference to the use of this small ore in open-hearth furnaces, steelmakers objected to it in such furnaces, the principal reason being that it was carried over into the checker-work and was lost; and that even if the fine Campanil, or other similar ore, was received into the slag or into the bath, it was not as effective as the lumpy material. Many years ago he had occasion to try the effect of fine ore. In this case it was a magnetically separated New Zealand iron sand. The sand, when thrown into the furnace, sank through the slag, and none appeared to be carried over into the checker. That sand was quite as effective as if it had been in a more lumpy condition. Unfortunately, the amount of material at his disposal was too small to make more than one single trial. He thought open-hearth steelmakers would do well to consider and make trials with such material. As a rule, they discarded all small ores, and would not have anything but lumpy ore. He saw no reason why magnetic iron ore sand should not be used in an open-hearth furnace with beneficial results. The consolidation of the ore by coking coal with ore mixed with it was not a new thing. Many years ago he was present at trials made in the old beehive coke ovens, in which purple ore was mixed with small coal and coked in the beehive ovens. The result was that the purple ore was partly reduced to pig iron or fluid cinder, which ran down to the bottom of the oven, and what remained in the coke made it very friable—in fact, in such a state that the blast-furnace manager refused to use it. In the Coppée and similar ovens, in which the heat was not so great as in beehive ovens, he considered that with magnetic ore (which was not, by the way, readily reduced) instead of purple ore, it was highly probable that, with a small admixture of this magnetic sand in the coal, one would be able to make a coke which was not very friable, and which might be utilised in the furnace with advantageous results. In Norway there were several fields of magnetic iron ore mixed up with quartzite and other siliceous minerals, and if small ore could be profitably utilised, possibly those fields might be opened out, and the magnetic ore separated, and sent to this country for use. The question was a very important one.

## *CORRESPONDENCE.*

The editor of the *Engineering News* (New York) points out that the paper on the use of concentrates in the blast-furnace gives a very good summary of the experience in this field of the metallurgists of Scandinavia. In the United States the very low cost at which the fine Mesabi ores have been delivered at furnaces has given a set-back to magnetic concentration processes during the last half-dozen years; but the present boom in the iron market will be likely to give them new courage. In general, he believes American operators of magnetic concentration plants have not crushed their ore very fine, being content to stand a little loss in the tailings rather than produce a material unsuitable for direct use in the furnace. As a consequence, concentrates, when used with care, have given little trouble in American blast-furnaces. The only case where briquetting of the concentrate has been attempted is at Edison's famous works in New Jersey. Here very fine crushing is a necessity to extract the ore, and the final concentrate is far too fine for direct use in the furnaces. It is therefore made up into briquettes with resin oil, and these after baking are ready for shipment to the furnaces.

Mr. H. Bauerman, when called on to reply, said he would like to add a few words of his own which were not in the paper, and which, of course, could not be there. The first was as regarded his friend Mr. James Riley. He had come across a statement of Mr. Riley's method, and if he had been writing the paper himself, he should certainly have referred to it, as it appeared to him to be one of the most practicable of all the methods suggested for agglomerating, But, of course, it would have been difficult to put that into a stranger's paper without his knowledge, and further, he knew perfectly well that they would have a statement from Mr. Riley himself which would be considerably more valuable than anything he (Mr. Bauerman) could have stated. With reference to the suggestion made by Mr. Snelus that a Gerstenhöfer furnace should be used for this class of reduction, he thought that would be exceedingly impracticable unless it were lined in some particular way. The use of carbon for agglomerating did not appear to him to be a good method. They did not want a mixture of a rich ore and a small quantity of carbon which had been intensely heated, as that would not be a very nice stuff to handle in the furnace. The object of putting carbon into the furnace was to reduce the iron and not to agglomerate it. He could not help thinking, therefore, that the real use of this material would be in the open-hearth furnace. It seemed to be the most natural use apart from practical difficulties.

The President said that as Mr. McNeill had no remarks to offer in reply to the discussion, it was his duty to propose a vote of thanks to the authors and the translator of these respective papers. The Gerstenhöfer furnace was one in which the heat was maintained largely by the combustion of the sulphur contained in the ore, and it was obvious how widely different the conditions were when they had a reducing gas instead of an oxidising atmosphere. He could hardly remember a paper which had given rise to such an interesting discussion, or one to which so much interest attached.

The vote was carried unanimously, and the following paper was read :—

# A NEW CASTING-MACHINE FOR BLAST-FURNACES.

BY RICHARD HANBURY WAINFORD, STOKE-ON-TRENT.

THE object of this paper is to bring before the notice of the members of the Institute a new mechanical apparatus for casting sandless pig iron in insulated moulds, so as to maintain a good crystalline fracture, equal to that of the pig iron made in sand beds, at a reduced cost of production.

Considering the great interest now taken by ironmasters and managers of blast-furnaces in the question of the substitution of mechanical methods for manual labour, as far as possible, without deterioration of the product, and more particularly with regard to the treatment of iron leaving the blast-furnace, the writer feels no further apology is needed for the presentation of this paper.

In this direction several devices have recently been brought out, but up to the present, particularly in this country, they have not been generally adopted. An examination of the reason for this delay reveals the fact that in each of these schemes the iron so cast has suffered in fracture. This deterioration, in point of texture, is due to—

1. The chilling of the iron through conduction in the mould.
2. The vibration to which the iron is subjected whilst solidifying.
3. The rapid cooling of the iron in water.

The result therefore is, that none of the machines hitherto brought forward for the production of pig iron have really met the needs of ironmasters in this country, and especially those who sell part, or the whole, of their production upon the fracture. The great advantages of sandless pig iron are fully appreciated by steel-makers, forge- and foundry-men; but hitherto it has been impossible to obtain this unaccompanied by inferior fracture, and this has, more than any other consideration, deterred ironmasters, otherwise disposed to adopt a mechanical system, from abandoning the present general practice of hand-labour.

An urgent reason for adopting mechanical appliances for the class of work under notice is, that the removal of pig iron from sand beds by hand-labour is arduous work, and the result is frequent trouble with workmen.

In designing this apparatus, certain features were considered absolutely essential for successfully dealing with molten iron as it leaves blast-furnaces, viz.:—

1. The pig iron must be free from sand, and should have as good a crystalline texture as that now cast on sand beds.

2. The apparatus must be simple in construction, with few working parts, and it must be so designed that the risk of breakdown or stoppage is reduced to a minimum.

3. The metal when in the moulds must not suffer disturbance by vibration or shock by rapid cooling. The moulds are therefore to be fixed, so as to remain perfectly still during the action of solidification.

4. The mould must of necessity be metal in order to provide for repeat work; but it must not be massive. In this way rapid abstraction of heat by conduction from its molten contents is avoided. It must also be insulated by some non-conducting and refractory material. By these means the molten state is maintained as long as possible, and solidification consequently delayed.

5. The cost of the apparatus itself must be moderate, and the machine should be capable of application to any existing plant and require a small staff of men to work it.

The writer hopes to satisfy the members of the Institute that the efforts made by the inventors to carry out the foregoing conditions have met with some measure of success in the apparatus to be described.

The drawings (Plate II.) show particulars of a machine capable of dealing with sixty tons of iron per hour. Briefly, *b* represents a 15-ton ladle; *aa*, a central inclined ladle-track; $c^1$, narrow-gauge railways, placed on either side of the ladle-track, upon which is travelled a controlling vessel, *c*, which is attached to the ladle by an arm. These narrow-gauge railways are placed horizontally, and at the outer side of them a line of forty moulds, *d*, is also placed horizontally; and underneath each line of moulds is run the waggon-lines on which stand waggons, $d^2$, to receive the contents of the moulds.

The full ladle is brought to the lower end of the inclined ladle-track. The controlling vessel is then attached to it, and both are hauled by means of a wire rope, along the line of moulds; at the same time the operator gradually tilts the ladle. The idea of the inclined plane is to avoid splashing of the molten metal, as by its use the lip of the ladle is kept low down and in a constant position with regard to the controlling vessel. After the metal has remained in the moulds a short period, the moulds are tilted over in pairs, as shown, by the hand-gearing *f*, and their contents delivered to the waggons $d^2$.

The moulds are constructed in a light, corrugated form, and are placed in semicircular casings, leaving a cavity or space between the moulds and the casings, in which is placed suitable non-conducting material. The corrugated form of the mould gives strength with lightness; and the question of lightness, combined with the non-conducting material, constitutes one of the chief points devised to avoid the chilling effect, and therefore preserves the texture in the iron. The moulds are made detachable, and by releasing the bolts at each end of the casing may be readily taken out and replaced. The casings holding the moulds are fitted at each end with trunnions, upon which they are revolved when required to be discharged. A locking gear is provided, as shown at $f^2$, and the spaces between the moulds close automatically during the operation of casting, as shown at *g*.

By these several means a continuous cast is obtained; the moulds are held perfectly still while the metal is solidifying, thus avoiding mechanical action during that period, and by insulating the moulds the chilling effect is also avoided.

From the drawings it will be readily seen that this machine has few working parts; the moulds may be cheaply and easily renewed, and the cost of maintenance will therefore be a small item.

The photographs and samples exhibited are taken from experiments carried out in the first place at Messrs. Palmer's Shipbuilding and Iron Company, and later at Messrs. Bell Brothers, Limited, Middlesbrough, the latter experiments dealing with Cleveland iron exclusively. In each trial, both as regards the samples and the photographs, a fracture is shown of a machine-moulded pig, with a corresponding pig from sand beds, cast simultaneously and from the same furnace. In the course of these experiments it was found that ten minutes was a sufficient time for the iron to set in the mould and be ready for tilting over; so that with forty moulds in a line, a capacity of from 15 to 16 tons is provided for. Taking each mould as containing about 8 cwt., and as ten minutes has proved sufficient time to allow the iron to change from the fluid to the rigid state and to be discharged, there should be no difficulty in filling the moulds every half-hour; and taking the two lines of moulds as shown on drawings, the daily capacity would reach 1440 tons. It is generally considered that a 15-ton ladle is the most convenient size; and provision should be made at the furnace for the necessary number of ladles to stand, in order to receive its maximum make. It may be added that up to the present, under unfavourable conditions, the moulds used have made thirty trials each, and do not appear to be any worse for wear. The unfavourable conditions being that the moulds were allowed to cool down between each cast; and in a machine casting every half-hour the temperature in the moulds would never get below 450° C.; and by keeping the heat up in this way better fracture results would be obtained, and the strain due to contraction and expansion of the mould would not be so severe.

The space occupied by the plant described is 96 feet long by 36 feet wide. The power required is only that of a 5 horse-power hauling engine, or other motor, for the purpose of travelling the ladle and controlling vessel. The number of men required to work this apparatus is as follows:—

1 man tilting ladle.
2 men luting and discharging moulds.
1 boy attending to engine or motor.

On the assumption that these workmen have 8-hour shifts, the labour cost will be about ½d. per ton cast.

In conclusion, it may be added that, when required to load into main-line waggons, side-tipping bogies would be used for receiving the contents of the moulds, and these would gravitate to a suitable point for discharging into railway trucks as suggested. If more convenient, conveyors might be placed underneath the line of moulds, which would raise the pigs to a sufficient height to allow of their being discharged into main-line waggons, &c.

## *DISCUSSION.*

Mr. E. WINDSOR RICHARDS, Past-President, said he had joined in the discussion at the meeting of the West of Scotland Iron and Steel Institute when Mr. Uehling's method of casting was brought before it. He had seen that apparatus in operation near Pittsburg, and he was bound to say that it worked fairly well. It was a very costly machine to put up; it required a great amount of space, and altogether they did not escape all their troubles by adopting this method of casting pig iron. There was, in his opinion, only one reason for adopting it. There was great trouble with the men who cleared the pig beds on Saturday nights and Sundays and Sunday nights, when the iron was not taken direct to the steelworks. The men who worked round about blast-furnaces to-day were extremely troublesome; they would not fill the furnaces properly, and they would not take the pig iron away properly. He would only adopt this method of casting if driven to extremities by the action of the workmen: no other reason would induce him to adopt the system, for although he would not say that it necessitated a complicated apparatus, the plan was undoubtedly expensive. Let them picture to themselves the machine he had mentioned. It was placed in a very long casting-house; it was operated by tolerably powerful engines, and the pigs—after travelling in the moulds for a considerable distance (the whole cast being in operation and travelling at the same time, with all the moulds of great weight)—were brought to the far end, and then tipped over into a trough of water. The pigs were next carried laterally in the trough in order to cool them down, and then raised again by a system of Jacob's ladders, and finally tumbled into the waggons. They had to use ladles, and these ladles had to be run round from the blast-furnaces and brought to this spot for casting; so that altogether there was a good deal of trouble and expense in it. Therefore, unless he was driven to it for the reason he had named, he should not think of adopting the system. He suggested that the President should invite Mr. Hawdon, who was adopting some system of casting pig iron direct from the furnace, to give them his experiences.

Perhaps Mr. Hawdon knew something of the new apparatus at Skinningrove for clearing the beds by electric machinery, which he had heard worked very well.

Mr. WILLIAM HAWDON was much interested in the matter of iron casting machines. He was rather sorry to hear the remarks which fell from Mr. Windsor Richards. As they all knew he was a very practical man. To himself it appeared that the matter of fracture, as pointed out by Mr. Wainford, was a matter of very secondary importance. He did not think, except where the iron was sent to small foundries, that it mattered at all what the fracture was, beyond the fact that it was an indication of the quality of the iron. He had taken a great deal of pains to find out from practical founders whether the chilling of the iron affected ultimately the quality of the iron after it was recast—remelted—in the cupola, and the invariable answer that he got was that it did not affect it in any shape or form. At the same time he was given to understand that at the works of Sir Lowthian Bell they had tried casting iron experimentally for the purpose of finding out whether it was affected in quality by the chilling or not, and he was told that it did affect it to some extent. He would be very glad to hear from Sir Lowthian Bell whether they found that the chilling of iron by casting it in moulds ultimately affected the quality of the iron after it was remelted in the cupola. They all knew, as Mr. Windsor Richards had pointed out, that they had very great trouble indeed with the men on the pig-beds, and his reason for designing a machine was to do away with this by dispensing with hand-labour as much as possible, and by removing the molten iron some way from the furnace and dealing with it in an open cool space. He could not agree with Mr. Windsor Richards when he said that such an apparatus was too expensive. He thought the pig iron would be dealt with cheaper than it was by hand-labour, and he also thought it was worth all the trouble in doing away with hand-labour. The author said "the metal when in the moulds must not suffer disturbance by vibration or shock by rapid cooling." He did not think it mattered at all whether they altered the fracture or not so far as the quality of the iron was concerned. The author also said that it was necessary to have the moulds light, and he made them in a corrugated form. His experience after a very long time, in dealing with slag at any rate, and with iron, was that they must have a massive form of machine. He did not think they could work a machine unless it was very strong indeed. He could not see that the machines which Mr. Wainford brought before them could deal with the quantity of iron where there was a daily output of 1440 tons. He assumed from the small drawing that each section cast four pigs, which the author said weighed eight hundredweight, leaving them two hundredweight each, which was very much too heavy to deal with in steel works. They should not be much more than half a hundredweight each—very little over that, at any rate. The author did not appear to cool down the pigs at all; he could not see how he was going to deal with them unless he used some cooling apparatus, which, of course, would add very considerably to the cost shown in the paper. He did not know that he had anything more to say with regard to the subject, except to emphasise the fact that so far as his information and experience went, it did not matter at all whether they altered the fracture of the iron so long as they kept it chemically right. He had not seen the clearing apparatus that Mr. Windsor Richards spoke of at Skinningrove which was worked by electrical power, but he believed it was very successful.

Sir LOWTHIAN BELL, Past-President, said Mr. Hawdon had referred to him with reference to the experiments which had been going on at the Clarence Works. He was sorry to say that all the experiments that went on at the Clarence Works were now more or less carried on without the supervision that he once gave them; but he might say this—that his sons, who were present on the trials, spoke favourably of the apparatus described. With regard to the alteration in the composition of the iron, that was not the only thing they had to deal with. In running pig iron into sand, as was well known, a considerable quantity of silica adhered to the pig iron. There could be no doubt of the prejudicial effect of the presence of silica in the cupola, or in the open-hearth furnace, in that it must lead to a great waste of iron. At all events, therefore, there should be a saving of metallic iron, more or less. With regard to his friend Mr. Windsor Richards, he did not think that he had treated the question with that lucidity which generally characterised anything he might have to say to them. Mr. Windsor Richards told them that unless he was forced to adopt a piece of apparatus like that by the attitude of the refractory character of the men, nothing would induce him to use it. But then Mr. Windsor Richards told them that these men were refractory and very difficult to deal with.

Mr. **Joseph Cooper** (Jarrow) thought it was only right to acknowledge that in a small way he had had something to do with the putting together of this machine, and therefore what he said now might be somewhat prejudiced. Some of them knew that he managed the blast-furnaces at Jarrow, where this insulated mould was first tried. The paper said they made about thirty tests with the mould, and in each case they had no chilling of the pig iron. The pig iron showed, as nearly as possible, the fracture of the iron on the pig-beds cast at the same time. In one or two instances it was not quite so good, and in one or two other instances it was slightly better. Mr. Hawdon had made a remark which he thought would be a surprise to many blast-furnace managers, and that was that the fracture of the iron was a matter of no importance whatever. He thought most blast-furnace managers would disagree with that remark. At any rate, it was a well-known fact that if they had to sell iron, and if they could sell it with a good fracture, and also a good analysis, they had certainly got a very great advantage over the man who could only sell an analysis alone and regardless of fracture. It was believed that none of the machines at present in use were able to guarantee a fracture. He thought, as far as he had been able to test it himself, that in regard to the fracture they had always turned out a poor No. 3 iron from a chilled mould when it was a No. 1 iron on the pig-beds. Further, they tried the effect of vibration. He got two iron chills, filled them simultaneously, and one of them he had tapped with a small hammer during the time it was solidifying. The difference in fracture between these two pigs was very remarkable. On that ground they concluded that it was necessary to have the moulds perfectly still; and by that means they got a further advantage, because they did not get the wear and tear of a machine that was conducted on the Jacob's ladder system. There was very little wear and tear in a casting apparatus where they had fixed moulds, the only mechanism being a small hand-wheel to turn over the mould for the pigs to drop out. They wanted, first of all, to provide a pig which would be equal in fracture to the pig-beds. That they had done, as was clearly proved by the samples exhibited. Secondly, they wanted to build a machine that would be cheap to put together, and one that would not be so expensive as the machines which had already been placed upon the market. Further, they wanted a machine which would be inexpensive in labour cost to work, and where the risk of a breakdown would be the most remote. He thought they had got that in this case. There were really no working parts about it, as the ladle itself did the whole of the work. The ladle was brought to the bottom of an inclined railway, and it began its work immediately when it got to the foot of that railway, and it was pouring out all the time it was being drawn along. There was another matter Mr. Hawdon referred to, and that was the weight of the pigs. As they would see by the drawing at the end of the paper, there were four pigs, 6 feet long, in each mould, with two notches on each pig, so that when the pigs dropped out of the mould on to the bogie placed below it, they separated into three pieces, each piece weighing about 70 lbs., which was not an excessive weight for any man to lift. He considered it was very desirable for every works in this country, even where there were only two furnaces working, that they should adopt a metal-casting machine, not only on account of the trouble one had to endure from the men themselves, but because of the arduous nature of the work of metal-carrying. In weather such as we were having now some of his own men had fainted on the pig-beds when they had had a heavy day's work to do in the excessive heat. Men ought not to be put to do such work when it could be done by machinery, and when, at the same time, enormous economies could be effected thereby. Mr. Wainford might have rather exaggerated the saving in cost of dealing with iron from the furnaces by the apparatus described, but still there was a very large saving to be effected by the adoption of a machine against hand-labour, for the machine could be erected at small expense, and could do the work as effectively as hand-labour.

Mr. R. A. HADFIELD, Member of Council, said the question was a very important one. In America, he believed, they were adopting the process of casting pig iron in chills on a large scale. One piece of information in the paper he was specially obliged for, and that was, that the method might be carried out at a very moderate cost per ton. He had obtained samples of sandless pig iron in this country, and the makers asked no less than ten shillings per ton extra for it. He quite agreed with Mr. Hawdon that casting pig iron in iron moulds would not affect the quality. He suggested that in this way those who were carrying out this process should make one or two crucible experiments—that they should melt some pig iron which had been cast in iron moulds, and some which had been cast in sand; take transverse bars of each, say one inch square, and obtain the breaking strength. He thought the results would be found to be identical. As they knew, Swedish pig iron was sent into this country cast in chills; but he did not think Sheffield makers had found any difficulty in using it. They simply went by analysis, which, after all, in his opinion, was the chief guide.

Mr. GEORGE AINSWORTH, Member of Council, thought there was some slight confusion about what Mr. Hawdon had referred to. He took it that for steelmaking purposes, whether Bessemer or open-hearth, it was a matter of indifference what the fracture was, so long as the analysis was right. He thought Mr. Hawdon's remarks had more reference to the question whether a pig cast in a chill, and consequently containing less graphitic carbon and more combined carbon than if it were cast in sand, would, when it came to be remelted in a cupola, make as grey casting as if it had been originally cast in sand. He believed they would all agree it would be a retrograde step, at any rate for the members of the Iron and Steel Institute, to attempt to consider that the fracture of a pig iron could determine whether it was fit for steelmaking purposes or otherwise.

The PRESIDENT was particularly glad that the question of the influence of fracture on the value of a pig had been so satisfactorily settled, because it did appear, after all, that analysis was the one test to which they must all refer. They were glad to welcome the remarks of the new member of Council on this important point. The paper had been of very great interest, and he had the pleasure of proposing a vote of thanks to Mr. Wainford for it.

The vote was carried unanimously, and the following paper was read:—

# IRON INDUSTRY IN THE TERRITORY OF HIS HIGHNESS THE NIZAM OF HYDERABAD DECCAN.*

By Shamsul Ulama SYED ALI BILGRAMI,
Assoc. R.S.M., B.A., LL.B., Secretary to H.H. the Nizam's Government Public Works Department, Railways, and Mines.

Before entering on the subject proper of the paper, it would not be out of place to give a short sketch of the geological structure of the country, as nearly two-thirds of the territory ruled over by his Highness the Nizam is covered with crystalline rocks, and presents features highly favourable to the formation of mineral deposits. Besides, so far as I am aware, a connected account of the geology of Hyderabad has not hitherto been published.

Geologically, the whole of India has been divided into two distinct zones—

1st. The Extra-Peninsular area, comprising the country lying to the west, north, and east of the Indo-Gangetic plain; and

2nd. The Peninsular area, viz. the triangular portion of the country situated on the south of the Vindhyan range of mountains.

The geological history of these two divisions is markedly distinct. Whilst the Peninsular area has been, since the latter end of the Palæozoic period, an area of dry land, and the coast-line has remained practically unaltered since that period, the Extra-Peninsular area has been the seat of marine deposits extending into the Mesozoic period.

---

* It was only about the middle of June that I had the pleasure of meeting my old friend and school-fellow, Mr. Brough, the Secretary of the Institute, and was induced by him to undertake the reading of this paper. The observations here recorded were made more than fifteen years ago, when I had a party of itinerant ironworkers attached to my camp, and made full notes of the process employed by them in the manufacture of iron and steel. Unfortunately, however, these notes and the drawings I then made are not available, as they have not as yet arrived from India. I must, therefore, beg the indulgence of the members for such imperfections as are unavoidable in the reproduction of facts from memory.

The Peninsula has undergone no great compression since the close of the Palæozoic period, while the Extra-Peninsular area has been greatly compressed and disturbed since the Tertiary period, resulting in the formation of such contorted and complicated mountain ranges as the Himalayas and the hills of the Punjab and Beluchistan.

Hence in the Extra-Peninsular area the mountain ranges coincide with special and well-marked centres of upheaval, the valleys are deep and steep, and the rivers are of a torrential character. On the other hand, the mountains of the Peninsular area are the remains of extensive table-lands, out of which the valleys have been carved.

The whole of the Peninsula, of which his Highness' dominions form a portion, is one vast table-land, the boundaries of which were defined and fixed towards the close of the Palæozoic period, and subsequently worn out by sub-aerial denudation, and on the coast-line by the sea,—the highest points, such as the Nilgiris, Pulneys, and Shevroys, being merely plateaus produced by the removal of the surrounding portions of the table-land. The Peninsular formations represented in the Hyderabad State are the following:—The Metamorphic Series; the Transition Series; the older Palæozoic Series; the Gondwana Series; the Deccan Trap, including Intertrappeans; the Laterite deposits, and Alluvial deposits and soils.

The metamorphic series consists of the gneissose rocks of the Peninsula, representing the oldest geological formation in India. The gneiss is composed of six minerals—quartz, mica, hornblende, chlorite, a red orthoclase felspar, and a white plagioclase felspar. But the varieties differ largely, and sometimes a gneiss may contain only two of these minerals and sometimes all. The variety most extensively developed in Hyderabad is the granitoid gneiss. Its eastern and southern boundaries are marked by the Godavery and Krishna rivers. In the north it extends up to Edlabad, in the district of Sirpur-Tandur, whilst its western boundary may be rightly defined by a line drawn from Nirmal through Indur to Tandur on the Nizam's railway, and thence through Yadgiri to the Krishna.

The hornblendic granite-gneiss of Hyderabad weathers in a remarkable manner, which to the untrained eye presents the appearance of ice action. Enormous rounded and smoothed boulders stand one over the other, and sometimes in groups, which surprise the newcomer. But a slight acquaintance with the nature of the rock at once shows that this appearance is due entirely to sub-aerial denudation. The granite-gneiss, through action of heat, splits vertically. These vertical cracks, reaching the planes of foliation, make the rock split horizontally along these planes, the result being a mural arrangement of broken pieces of rock. Rain and wind then commence their action. The corners of the rock pieces get rounded off, the side pieces fall off, and the result is one huge rounded piece standing over one or more pieces of the same kind, which all formed originally a portion of one and the same rock.

The metamorphic series may be taken to be of the archæan zone, although, in the absence of fossils, no true correlation can be made.

The rocks of the transition series represented in Hyderabad are the so-called "Dharwars," the gold-bearing rocks of Southern India. The Dharwars consist of hornblendic, chloritic, and argillitic schists, associated with more or less hæmatitic quartzite and numerous contemporaneous trap flaws. They are developed chiefly as long bands and outliers, highly disturbed and folded into the gneiss.

The Dharwar system has become of great importance from the fact that it carries all the auriferous quartz reefs which are of any value in Southern India. Although the outcrops situated in the Mysore territory appear to be the richest, gold is found in all of them. These quartz reefs have been mined from prehistoric times, and old workings, some of which are more than 300 feet deep, are to be found over the whole area, and still offer the best indications of the richness of a lode.

In the vicinity of these old workings are to be found groups of "mullackers," or mortars of large and small size in the rocks, in which the primitive miners pounded the ore. They are to be seen in abundance at Topaldodi. At Wandali there are large saucer-like hollows made in the trappoid rock in which the ore was pounded by means of rounded granite crushers of great size and about a ton in weight. These crushers must have been brought from a great distance, and from their enormous size it is evident that they were not worked by hand, but by means of some sort of framework which afforded leverage.

In one of the pits at Wandali, known as the West shaft, a human skull was found at a depth of 210 feet from the surface. This skull, which is evidently that of a person past the middle age, is small and narrow, and presents a great many characteristics of the primitive human skull. A complete investigation and examination of this skull is still awaited.

The older Palæozoic rocks, the so-called Cuddapah and Kurnool series, consist of quartzites and limestones. They are considerably developed in the north-western portion of the Dominions, attaining a thickness of over 5000 feet, and are locally known as the Pakhal series, being situated in the neighbourhood of the famous Pakhal lake. The limestones are pale, dark grey, or buff-coloured, seldom red; are well-bedded, and have occasional layers of ribbon jasper. They are overlaid by fine-grained earthy shales, which are usually some shade of red. Although these beds, by their texture and undisturbed condition, are eminently fitted for the preservation of organic remains, no fossils have hitherto been discovered in them.

The Kurnool proper do not occur in the Hyderabad territory, but closely related to them and resembling them in lithological character are the rocks of the Bhima series, so called from the river of that name passing through the centre of the outcrop. On their north-western border the Bhimas are covered by the Deccan trap, while throughout their north-east border, for a distance of more than 100 miles, they rest immediately upon the gneiss. They extend from Kotapalli to the G. I. P. Railway between Gulburga and Shahabad, and then on to Parvatabad, where they take a bend to the south, passing by Loni and Talkota.

The Bhima series is chiefly a limestone formation, although beds of quartzite occur in the upper, and sandstone and conglomerates in the lower portion of the series. But these are purely local, and in some sections the series is exclusively made up of limestone. The limestones are fine-grained, with a texture approaching lithographic stone. The grey colour prevails, but pink and drab tints are not uncommon. The rock occurs in flaggy beds and is largely used in building, and especially for flooring. The pale variety is preferred, although the grey is the more durable. The stone is capable of taking a very fair polish, and has been used, though sparingly, for tables in place of marble.

The older Palæozoic rocks are certainly older than the Permians of Europe, and some of the lower groups may be correlated with the Precambrians.

## THE GONDWANA SERIES.

The term Gondwana is derived from the ancient name of the countries lying to the south of the Nerbudda river, which were Gond kingdoms, and are now included in the Jubbulpur, Nagpur, and Chattisgarh divisions of the Central Provinces.

The Gondwanas, which are the first fossiliferous series of the Indian Peninsula, consist chiefly of sandstones, shales, and, with the exception of the beds exposed along the east coast, appear to have been entirely deposited in fresh water and probably by rivers. Amongst the fossils found, animal remains are very rare, and the few which have been found belong to the lower classes of vertebrata, namely, reptiles, amphibians, and fishes. The bulk of the Gondwana fossils are plant remains, and there is evidence of several successive floras.

The Gondwanas form very poor soil, ill suited for cultivation, and thus vast tracts of country where these rocks occur constitute wild uninhabited forests, or, from the decomposition of the sandstones, loose sandy plains completely concealing the rocks below.

The Gondwanas have been divided into an upper and a lower series. The lowest member of the group has been called the Talchirs, from a small district of that name, being one of the tributary mahals of Orissa. The Talchirs consist of fine silty shales and fine-grained soft limestone, and are nearly always present in every extensive deposit of the Gondwanas. The shales are of a greenish-grey or olive colour and sometimes slaty. Their texture is exceedingly fine, and they are traversed by innumerable joints, which cause them to break into minute angular fragments.

The Talchirs present three distinct peculiarities:—Firstly, in the shales and fine sandstones, generally towards the base of the group, but frequently several hundred feet above the bottom, rounded and rolled pebbles and boulders occur, which vary in size from fragments of a quarter of an inch in diameter to large blocks of fifteen feet in diameter. As these boulders are found embedded in the finest silt, it is believed that they were rounded by torrents, but transported to their final position by the action of ice. In this so-called boulder-bed we have, therefore, the remarkable fact of the existence of floating ice in the Gondwana period in a latitude of about 16° north of the equator. Secondly, the Talchir fine shales have a strong resemblance to volcanic rock, and even the sandstone is somewhat like a decomposed basalt both in colour and mode of weathering. So great is this similarity, that several observers have classed the Talchir beds as Trappean. Thirdly, the Talchirs have a remarkable power of resisting disintegration, and consequently the places where they are not covered by an alluvial deposit are absolutely barren, as they themselves do not decompose to form soil. Thus, along the edges of the coalfields where the Talchirs are usually exposed, one might walk miles over broken pieces of greenish-grey shales without meeting with any vegetation.

The fossils hitherto found in the Talchirs are few in number. Of animal remains, only the wings of neuropterous insects and some annelid markings have been discovered. The plant remains consist of two species of Gangauopteris and one species of Glossopteris, and a plant resembling *Nœggerathiopsis hislopi*, but hitherto not distinctly identified.

The next beds of the lower series in ascending order are the Barakars and Kamthis.

The Barakars consist of sandstones of various kinds, shales, and coal. The sandstones are often coarse and felspathic, massive in form, and, from the decomposed felspar, of a pale or white colour. Another characteristic is that the Barakar rock is a conglomerate of small well-rounded white quartz pebbles, the matrix being usually a white sandstone.

Although the white felspathic variety is the typical sandstone of the Barakars, and occurs in areas so widely apart as Bengal and Chanda and the Godavery valley, brown, red, yellow, and other colours are also found.

The coals of the Barakar beds differ widely in different coalfields. But they all agree in possessing a peculiarly laminated appearance, due to alternating layers of bright and dull-coloured coal, the best coals being those in which the bright layers predominate. Although the Barakar coal of many areas affords an excellent fuel, it is somewhat inferior to the average English coal.

The Barakars are the true Coal Measures of the Peninsular area, and it is interesting to note that in this area, at least, the formations, which in point of time correspond to the true carboniferous rocks of Europe, are not coal-bearing, whereas the Coal Measures of the country correspond stratigraphically to what may be called the Permio-Triassic age. In the Extra-Peninsular area, however, coal has been found in various younger deposits.

Fossils are not common in the Barakars, and, when they do occur, they consist usually of Glossopteris or Vertebraria, a plant of doubtful nature, which probably belongs to the family Equisetaceæ.

The beds overlying the Barakars in the Godavery valley have been described as Kamthis, from the well-known military station of that name situated twelve miles to the north-east of Nagpur.

The Kamthis consist of conglomerates, grits, sandstones, shales, and clays, and are somewhat rich in fossils, &c. Two genera of Equisetaceæ, namely, *Phyllotheca indica* and *Vertebraria indica,* seven species of Glossopteris, two species of Macrotœmopteris, and *Nœggerathiopsis hislopi,* with some others, are represented.

These three beds of the lower Gondwana series extend in an unbroken stretch from the Wardha valley to within a few miles of the deltaic deposits of the eastern coast near Ellore.

Within this area, the Talchirs, although exhibiting everywhere the characteristic "boulder-bed," are poorly developed. The Barakars too—the only true coal-bearing beds of Hyderabad—attain only a small thickness. On the other hand, the Kamthis are very extensive in superficial area, and at the same time attain great thickness. Thus, while the Talchirs may be put down at 200 feet, and the Barakars at 300 feet, the Kamthis are quite 4500 feet at their thickest. Proceeding from the south to the north, the coal-bearing Barakar beds have been found at the following localities in the dominions:—Kunnigiri, Madavaram or Damercharla, Singareni, Alipalli, Kamaram, Hundella, Chinur, Tandur, Aksapur, Antergaon, and Sasti.

## THE DECCAN TRAP.

Within the limits of the Peninsula the Deccan traps in superficial extent are exceeded only by the Metamorphic series. They are not so thick as the Vindhyans or Gondwanas, but their remarkable horizontality enables them to conceal all older rocks. They form one of the grandest masses of bedded traps in the world, possess a vertical thickness of 4000 to 6000 feet, and cover an area of 200,000 square miles, which probably was much greater originally.

The Deccan traps consist chiefly of basaltic lava flows, assuming for the most part the form of dolerite, but great structural variation occurs, some being excessively compact and homogeneous, and others coarsely crystalline, containing olivine, and one variety at least containing large tubular crystals of glassy felspar, white or green in colour. Secondary minerals of various kinds, which crystallised out since the consolidation of the trap, are found in abundance, not only in nodules distributed through the rock, but lining all the cavities and creeks. They consist chiefly of quartz, either crystalline or in the form of agate, bloodstone, jasper, &c., and of zeolites in the shape of stilbite, prehnite, apophyllite, and calcite. The green mineral glauconite is very common.

The Deccan trap flows probably took place from vents without the formation of regular volcanic cones, as no traces of inclined beds of such cones have been found. From the mass of evidence available it appears that these flows must have occurred between the Upper Cretaceous and Lower Eocene periods.

The geological structure of the trap imparts a peculiar feature to the country which is covered by this formation. We find great undulating plains separated from each other by flat-topped ranges of hills, the sides of these hills being marked by the terraces caused by the unequal weathering of the hard and soft basaltic strata. The soil produced by the disintegration of the basalt is the rich black earth called black cotton soil, which retains moisture and does not require irrigation to the same extent as the soil of the gneiss country.

The Deccan trap has a very large development in the Hyderabad territory, covering nearly half the area and occupying the northern and western portions of the Dominions. Its northern limit lies in the vicinity of Edlabad, in the amaldari of Sirpur Tandur, and along the southern boundary of the Assigned Districts of Berar up to Ajunta, where its western boundary may be traced along the boundaries of the districts of Aurangabad, Bir, and Naldrug. On the east and south the trap area is bounded by a line running from Nander through Kaulas to Bidar, and then curving round by Valal towards Gulburga and then to Sagar.

An intertrappean bed of small extent, with its characteristic fresh-water Physa and Lymnea, has been known to occur near Shankarpalli, a station eighty-eight miles east of Wadi junction.

## THE LATERITE.

The close of the volcanic outbursts left the peninsula of India as a vast basaltic plain which has been subsequently carved into hills and valleys by subaerial denudation. The only formation resting on the Trap, with the exception of the alluvial deposits, is the so-called Laterite, which, in its normal form, is a porous argillaceous rock, much impregnated with peroxide of iron distributed irregularly through the mass, and which attains a thickness of from 40 to 200 feet. The exposed surface of the laterite is extremely irregular, caused by the washing away of softer material, and is traversed by tubes and cavities.

The iron exists either as pure hydrated peroxide, viz. limonite, or partly hydrated and partly anhydrous. This limonite forms a brown exterior glaze, and gives the rock a mammillated and botryoidal appearance, bearing a strong resemblance to scoriaceous igneous product. The quantity of iron in the laterite varies in different localities, but the richest varieties contain as much as 46 per cent. of the peroxide of iron. The laterite has been worked as an iron ore in many parts of India.

The laterite has a remarkable power of resisting disintegration, and wherever a cap is found on a hill, the lower portion is covered with reconsolidated *débris*. This is explained by the fact that, owing to the great agglutinative properties of the hydrated peroxide as soon as disintegration takes place, the disintegrated material is at once reconsolidated and converted into the original rock.

Like the Deccan trap, the laterite is largely developed in Hyderabad. Besides the remarkable occurrence of it at Bidar, the rock is found extensively developed at Vikarabad, and the Anantagiri hills are capped with it. At Vikarabad it attains a thickness of from 50 to 100 feet, and imparts to the water of all the wells in this growing town the characteristic iron taste and tonic properties.

The age of the laterite is undetermined. In fact, taking into consideration its occurrence at different heights, and taking it to be the result of the alteration of the underlying beds *in situ*, it is probable that it was formed at different ages and up to very recent times.

### ALLUVIAL DEPOSITS.

The two great rivers which traverse the territories of his Highness are the Godavery and the Krishna. Of the alluvial deposits of the Godavery those of interest occur along the upper part of the river, in the neighbourhood of Paitan. Here siliceous wood of all sizes has been found, and even mammalian bones identified as *Elephas*, *Numadicus*, and *Bos* were discovered some time ago.

From the gravels near Mungi and Paitan, which are the chief localities for the fossil bones, Mr. Wynne obtained an agate flake, apparently of human manufacture, thus affording a second example of the trace of man in the Pleistocene gravel beds of the Peninsula. At a place near Hingoli fossil bones are said to have been found in large quantities, but these were unfortunately not preserved.

The only alluvial deposits of the Krishna which are of any importance are the diamond gravels lying on the left bank of the river, near the junction of the Munair. The deposits consist of sandy shingle beds, the shingle being composed chiefly of quartzite, and have been worked for diamonds. The gravels lie at considerable levels above the river, and are covered by black cotton soil.

The soils are chiefly those resulting from the decomposition of the overlying rocks, and consist of varieties of sandy soil, red and white moorum, and regur. The regur is a black or brown argillaceous soil, generally impregnated with varying proportions of lime. It is thick and sticky when wet, but when dry light and friable and traversed by cracks. It retains moisture long, and is generally associated with the trap-rock from the decomposition of which it has originated.

## IRON ORE.

Having given a sketch of the geological features of his Highness' dominions, I shall now describe the various ores of iron found in the territories, and the primitive processes by which iron and steel have been manufactured from time immemorial, and are to this day manufactured from these ores, concluding with a brief consideration of the prospects of reviving the industry on a large scale by the employment of European capital and the introduction of modern methods of working.

Iron ores of the very best kind, consisting chiefly of hæmatitic and magnetic ores, occur extensively in many parts of the dominions. From time immemorial the iron of the Nizam's territories has been worked at Yalgharab, Nirmal, Juctial, Warangal, and other places into blooms, from which cast steel of a very superior quality was manufactured and exported to the far West. It has been proved that the raw material from which the famous Damascus blade was manufactured was obtained from an obscure village in the Nizam's territory. Besides the magnetic ores, a titaniferous ore is found abundantly in nullahs in the Warangal district. Yellow and red ochres are also obtainable, and an ore found at the junction of the trap and laterite was obtained in the Medak and Elgandal sircars and largely worked. The ore used in the manufacture of the best Nirmal steel was a mixture of a magnetic sand and an earthy ore from the laterite in the proportion of 3 to 2.

I shall now take the ores *seriatim*.

*Magnetite.*—This is by far the commonest ore, and occurs in great abundance in the whole area covered by the crystalline rocks. It is found diffused in the granite-gneiss, in schist, as well as in the sandstone. The hard rock* occurs in beds and along ridges, but the process of oxidation and hydration causes the expansion and the disintegration of the compact mass, producing a friable rock easily breakable into small fragments which come down the hillside and form a kind of talus. It is these fragments which are generally collected by the native workers, as they are not only easily obtainable, but are also easily reducible in their primitive furnaces. Magnetite is also very largely found in the sands of rivers, being the result of a further disintegration of the friable rock described above. Although in this form the grains of magnetite are mixed with minute fragments of nearly all the constituent minerals of the gangue rocks, the running water which washes down the disintegrated material causes natural concentration, the heavier grains of magnetite becoming separated from the lighter fragments. The jet-black sand thus produced is very pure and shows distinct magnetic polarity.

Small quantities of magnetite are also found diffused in some of the basalts of the Deccan trap, but these are of no economic value.

Through the kindness of Mr. William Morgans, the Consulting Mining Engineer to the Hyderabad Deccan Company, I am enabled to exhibit two pieces of a magnetic ore from a locality in close proximity to the Company's collieries, and also to submit analyses of two different samples, made by Mr. Stanley H. Ford of Bristol:—

| | Sample No. I Weathered. | Sample No. II. Unweathered. |
|---|---|---|
| Iron . . . . . . . | 65·32 | 67·29 |
| Oxygen . . . . . . . | 24·88 | 25·63 |
| Silica . . . . . . . | 4·94 | 4·19 |
| Sulphur. . . . . . . | 0·062 | ·050 |
| Phosphorus . . . . . . | trace | trace |
| Moisture . . . . . . | 3·22 | 2·47 |
| | 98·422 | 99·630 |

These analyses speak for themselves. They show a fairly high percentage of iron, while of the two constituents of iron ores which are prejudicial to the manufacture of high-class steel, the percentage of sulphur is inappreciable, and of phosphorus only traces are found.

Mr. Foote, of the Geological Survey of India, in his traverse of the country between the Singareni coalfield and the Krishna river, came across an extensive deposit of magnetite iron ore situated about 2½ miles to the east of the village of Singareni, and running north and south. From south to north the deposit increases in thickness, forming a hill nearly 150 feet high just under the parallel of 17′ 30″ north. To the north of this point the beds are traceable for about half a mile and rise to a height of 250 to 300 feet.

This traverse was made in 1884, that is, before the opening of the railway and the development of the Singareni coalfield, and Mr. Foote rightly observes:—

"The ore in these beds is very rich in quality, and really appears to have been placed here by Nature in order that an iron industry might arise as soon as the Coal Measures close by are made to yield up their carbonaceous treasures."

Hæmatite occurs both in the crystallised form and as specular iron ore. At Tatpully, in the Indur district, a light brown ore is found at the junction of the trap and the laterite. This ore was highly valued in olden times, and was largely used in the manufacture of the famous Kunasamudrum steel, which was exported to Persia.

The occurrence of a titaniferous ore in some of the smaller streams of the Warangal district has already been noticed.

The Laterite formation has been fully described in the first part of this paper. Although the richest varieties contain as much as 46 per cent. of metallic iron, this ore is not much used for smelting.

Disintegrated magnetite, when obtainable, is the ore generally preferred by the native workers, but where the massive rock occurs, it is generally broken up with picks, and is further pounded by means of wooden mallets.. Where sand is used, it is generally concentrated by means of washing.

As regards the native method of extracting iron in the malleable state directly from the ore, it has remained unaltered since the time of Buchanan, who was one of the earliest observers of the process, and whose description and drawings, with slight modifications, stand good to this day.

In the Nizam's territory the process and the appliances have remained in the most primitive stage, and the art of smelting is carried on by the lowest caste of people.

In former years, when forest laws did not exist, every kind of hard wood was cut down for the purpose of making charcoal; but since the establishment of a Forest Department the field of choice has been narrowed down to such woods as are not preserved, and at the present moment only woods like the *Acacia arabica* and the *Butea frondosa,* of which latter nearly thirty species exist in the Hyderabad forests, are used for charcoal-making. Sometimes, though rarely, bamboo charcoal is used. The Hyderabad State, at any rate in those districts where iron-smelting is carried on, is rich in forests, and here the question of fuel has not pressed so hard on the iron-workers as it has in the comparatively bare and treeless district of Salem. Besides, British forest laws are a great deal more stringent than ours, and it thus happens that iron-smelting is still extensively carried on in the State, and no less than twenty distinct localities are known where the manufacture is in a more or less active condition. It must also be remembered that there is no Arms Act in the Nizam's territory, and the whole population practically carries arms. Moreover, large quantities of arms are required for the irregular levies of the State, and for the armed retainers of the very large and powerful landed aristocracy of the country, so that there is a very considerable demand for the product of these forges. The rules and regulations for the importation of arms and ammunition into native states are so beset with red-tapeism that the bulk of the population is compelled to fall back upon the country produce, and at the present moment the swords, daggers, and rapiers made in Hyderabad are practically as good as those manufactured hundreds of years ago.

The furnace used is the one described by Dr. Percy as of the *first kind.* It is 4 feet high, and is made in two parts of almost equal height, a stout base and a chimney. The base, which is 2 feet in diameter, is made out of clay, with admixture of sand and straw, and the chimney, which narrows at the top to about 8 inches in diameter, is made of a better kind of clay, and is fixed on to the base and plastered over. A semicircular hole at the bottom of the base serves for the insertion of the tuyere, as well as the removal of the bloom at the end of the operation. The tuyere is a clay tube about 7 inches in length, slightly widened in front to receive the nozzles of a pair of goatskin bellows, which conduct the blast, and are worked by hand.

The furnace is first filled with charcoal and fired through the tuyere. The bellows are then set to work, and when the furnace is well heated a charge of ore, moistened with water, is thrown in from the top. Quantities of ore and charcoal are then added from time to time, and in from three to four hours the operation is complete. The front part of the furnace is then broken, and the spongy mass of iron, which is by courtesy called a bloom, is taken out, and while hot is hammered into an irregular piece of wrought iron, which is afterwards cut up into bars. I have several of these bars in my possession, and I have been told by those competent to judge that the iron is of excellent quality.

The blooms I got out weighed from 15 lbs. to 20 lbs. Four men were employed on the furnace, and could work only two charges a day.

Reference has already been made to the Hyderabad steel and the manufacture of the famous Damascus blades from it. Steel is made in the usual way by the carburisation of wrought iron in earthen crucibles. The wood used is a species of cassia, very common in the country, and known as *Cassia tora,* and the leaves are those of *Calatropis gigantea.* The genus Calatropis has played an important part in the religious industrial and political history of the East. One of its species, the famous Soma plant, was the chief ingredient from which the well-known exhilarating beverage was made which the priests, both of the Hindus and the Parsis, used so largely in their sacrifices, and under the influence of which they saw things unseen by human eye. A whole book of the Rig-Veda and many hymns of the Zendavesta have been devoted to a description of the virtues of this sacred plant; and so important is the question of its habitat in relation to the early home of the Aryans, that full descriptions of the shrub were furnished to the Afghan Boundary Commission, whose labours lay in the region assigned by the early school of German Orientalists to the original settlement of the Indo-Germanic races. The species gigantea, still highly valued for its numerous medicinal properties, has helped to manufacture the renowned Indian steel—the *ondanique* of Marco Polo—which supplied many a true blade girded by Asiatic conquerors of yore, and may be said to have overthrown dynasties and established empires.

I shall now briefly consider the prospects of reviving the iron industry in the Nizam's territories on a large scale, by the employment of British capital and the application of modern methods of working.

My friend Mr. Brough has been kind enough to place at my disposal some of the recent literature on the subject of iron-making, and I have particularly read with interest Mr. T. Turner's paper on the production of wrought iron in India, and the correspondence on it, published in the Journal of this Institute in 1893. The communication from Mr. Ireland, in which experiments on a large scale with the Warora coal are recorded, is of special interest to those interested in the manufacture in India of iron and steel.

I may mention that the conditions in Hyderabad are somewhat different from those obtaining in the other parts of India, where the experiment of manufacturing iron on a large scale has been, either under the auspices of the Government or by private enterprise, tried and proved unsuccessful. As regards Government works, it is well known that in all commercial concerns undertaken by an organised Government, the cost of supervision is so great, and the selection of the superintending authority made on such uncommercial principles, that failure is almost the inevitable result. Of the private companies, so far as I am aware, the only one which has worked under anything like the favourable conditions which obtain in Hyderabad is the Bengal Steel and Iron Company, whose works at Barakar, I understand, are yielding a profit.

You will have noticed that in the Hyderabad State we have most extensive deposits of a high-grade magnetic ore in close juxtaposition with a large coalfield, yielding coal of as good a quality as the best Bengal coal. I may add that large deposits of Kadappa limestone, estimated to be 50 feet in thickness, and of which I am able to exhibit a specimen, occur quite close to the colliery. An analysis of this limestone, as made in 1891 by Mr. Claudet, is given below :—

| | |
|---|---|
| Carbonate of lime | 53·60 |
| Carbonate of magnesia | 43·90 |
| Oxide of iron | 1·05 |
| Siliceous rock | 0·90 |
| Carbonaceous matter and loss | 0·55 |
| | 100·00 |

I am assured that limestone of a much better quality is also found in abundance in the same locality.

Subjoined are two analyses of the Singareni coal, taken from the lower part of the so-called King seam, which prove it to be of excellent quality.

| | Sample I. | Sample II. |
|---|---|---|
| Carbon | 67·39 | 70·27 |
| Hydrogen | 3·83 | 4·78 |
| Sulphur | 1·24 | 0·27 |
| Oxygen and Nitrogen | 12·89 | 10·68 |
| Ash | 7·95 | 7·50 |
| Moisture | 6·50 | 6·50 |
| | 100·00 | 100·00 |

These analyses were made so far back as 1889, since which time the coal has much improved in the deeper workings. The present daily output is between 1200 and 1300 tons, and the extent of the Coal Measures being, at the lowest computation, more than 8 square miles, and the quantity of available coal from the King seam alone being 47,520,000 tons, the supply may be assumed to be inexhaustible.

We have thus the ore, fuel, and flux occurring almost together. The labour question has already been tackled and solved in the working of the Singareni collieries and the gold properties of the Hyderabad Deccan Company in the Raichore Doab, and nothing but English capital and modern appliances are required to establish a thriving iron and steel manufacture in the premier native state of India.

The late Sirdar Diler Jung, to whose energy and perseverance the present railway and mining development of Hyderabad is largely due, was extremely anxious to establish iron and steel works at Singareni, and wrote a long memorandum on the subject, in which he proved that the total capital required would not exceed £150,000, whereas the estimated profits would amount to £20,000 per annum, out of which, after paying 6 per cent. on the capital, a sinking fund of £11,000 could be formed, which would repay the capital in fourteen years. This may be too glowing a picture, but there can be no doubt that a reasonable

NAWAB SALAR JUNG BAHADUR

amount of capital invested in ironworks in the Singareni field would, with proper management, yield a very quick and satisfactory return.

It has always been a wonder to me why English capital would not invest itself in India without being propped up by a Government guarantee, while it would flow most freely and profusely into the uninteresting and miserable South American Republics, or lose itself amongst the arid plains and gilded sands of Coolgardie. Perhaps this is one of the mysteries of that marvellous organisation, the Stock Exchange, reserved for the esoteric circle which no outsider is permitted to fathom.

India has always been the home of iron and steel manufacture, as is amply proved by the enormous slag accumulations scattered all over the country; and if her ancient appliances are too primitive to compete with the requirements of modern trade, there seems no reason why, as a British dependency, English capital and English enterprise should not be forthcoming to utilise her great natural resources in ore, flux, and fuel, and restore her to her former position as one of the greatest iron manufacturing countries of the East.

The PRESIDENT said that the School of Mines men who were present would especially welcome this contribution from one of their colleagues. In connection with it would be taken the paper by Major Mahon. He should just mention that that paper, although it a little wandered from their strict rule, as it dealt to a certain extent with economic questions, was nevertheless so useful, taken in connection with the one they had just heard, that it could not fail to be of interest.

# INDIA AS A CENTRE FOR STEEL MANUFACTURE.

BY MAJOR REGINALD HENRY MAHON, R.A. (COSSIPORE).

THE object aimed at in this paper is to place before members of the Iron and Steel Institute facts relating to the possibility of manufacturing iron and steel in India at a profit.

If it can be shown that suitable material can be collected and worked into steel at a given centre in India at a price not exceeding similar manufacture in Europe or America, it must then be conceded that such steel starts in the markets of the East with an advantage equal to the freight charges on imported material. This advantage would never be less than 12s. a ton, and would rise at times to 18s. There should, however, be deducted from this the freight charges from the selected centre to other ports: this deduction could not under any circumstances absorb the whole. The cost of the Suez Canal passage (say, 4s. per ton), and some gain due to decreased lead, must ever be on the side of local produce, even when distributed under the most unfavourable conditions.

India alone, as a market, is capable of taking a very large quantity of manufactured steel, and its requirements are certain to increase for a number of years. In the year 1897–98 the imports of rolled iron (including plates) were 137,000 tons, a very large part of which would be accepted in mild steel. During the same period rolled steel, excluding rails, amounted to 80,000 tons; rails and fish-plates accounted for 93,000 tons more. In addition to this, 30,000 tons of iron pig and iron pipes were imported, and 43,000 tons of iron and steel sleepers. The sum total of these figures is 383,000 tons. Machinery and rolling-stock for railways was also purchased to the value of about 40 millions of rupees (about 2½ millions of pounds). Of the entire quantity of iron and steel imported into India, one-third of the iron and one-half of the steel comes from countries other than the United Kingdom.

The coal output of India has quadrupled during the last ten years, and now amounts to over five millions of tons annually. The average cost price at the pits is Rs.2 per ton (2s. 8d.). The greater part is good steam-coal, and a coke can be made from it which is singularly free from sulphur (0·5 per cent.), and contains from 10 to 12 per cent. of mineral ash. It is hard, tough, and well suited for the blast-furnace. The best and largest coalfields, containing many thousands of millions of tons, are situated about 150 miles from Calcutta, and are connected thereto by more than one line of railway.

Iron ore exists in large quantities in several localities. Of these the three best known are—

1. *The Salem District of the Madras Presidency,* situated about 113 miles from the sea at Porto Novo, where, however, there is no harbour, and about 199 miles from the port and harbour of Madras. These deposits are inexhaustible, and consist mainly of magnetite and hæmatite mixed with quartz. The ore is capable of being concentrated by hand-picking to a grade of from 55 to 60 per cent. of iron, 10 to 15 per cent. of silica, and unimportant amounts of sulphur and phosphorus. The small ore and tailings can be concentrated magnetically to 66 per cent. of iron and 3 per cent. of silica.

2. *The Chanda and Jubulpur Districts of the Central Provinces* contain an inexhaustible supply of fine red hæmatite of 60 per cent. grade, but unfortunately situated so far inland as to be heavily handicapped. On the completion of certain railways at present projected, the rail distance between the ore and the east coast at Masulipatam will be about 360 miles.

3. *The Iron Ores of Bengal.*—These are widely scattered, and do not, as in the previous cases, occur in enormous masses at a given locality. Their grade is from 40 to 50 per cent. of iron, and in many cases the ores are phosphoric. They lie, however, in proximity to the coalfields, and form the source from which the present Bengal Ironworks draws its supply, turning out a pig iron of which the approximate composition is—

| | Per Cent. |
|---|---|
| Silica | 2·26 |
| Sulphur | 0·02 |
| Manganese | 2·69 |
| Phosphorus | 1·98 |

The limestones of India are not at present well explored. It is probable that any large ironworks would draw its supply from the Burmese coast, where quantities exist of a purity of 97 per cent. of carbonate.

In India the Government minimum rail freight for goods is one-tenth of a pie per maund (80 lbs.) per mile, or 2¾ pies per ton-mile, equivalent to a little under one farthing per ton-mile. There is no doubt that for such traffic as would be necessary for the supply of a large works the minimum rate of carriage for ore and coal could be counted on. In the case of water-carriage, the obtainable terms would probably be less satisfactory. The coasting trade is practically the monopoly of a single company, and their vessels are not adapted to the rapid loading and unloading of such cargoes as ore and coal. If any scheme that may be adopted involves coastwise carriage for any of the material, the promoters will do well to provide their own shipping, specially designed for the trade.

After due consideration, I have come to the conclusion that the neighbourhood of Calcutta is the most favourable for the site of an iron and steel works. We have here a port open at all times of the year to shipping; the centre of a great network of railways spreading north, south, east, and west; the greatest trade centre in the East, and a labour market in which the natives have already been trained to the use of machinery, to iron-founding, and, in the case of one establishment, to steel-making.

That Calcutta is 800 miles by sea and 200 miles by rail from the Salem ore, and 150 miles from the Bengal coal and ore, need not alter the opinion expressed. Most of the readers of this paper are aware that conditions as unfavourable govern the manufacture of hæmatite iron both in England and in the North-Eastern States of America. Proximity to the sea is a factor of immense importance in any country, and proximity to a great centre of civilisation appears to the writer a factor of almost paramount importance in the East.

The conditions, then, which appear to offer the greatest prospects of success are:—the establishment of a steelworks on a large scale, capable of undertaking the whole or a large part of the requirements of India, both as to rails, sections, and plates—

a situation either on the Hooghly below Calcutta, or on the Mutlah River at or below Port Canning;—this latter site has considerable advantages, which will be enhanced if, as is proposed, it becomes the coal export depot for Bengal—the supply of coal to be drawn from mines owned by the steel company in Bengal, and the supplies of ore in great part from the magnetite deposits of the Salem district of Madras, and to some extent from the argillaceous ores of Bengal, the supplies of limestone coming by sea from the Burmese coast—all sea transport to be in vessels owned by the company and designed for the trade—labour-saving machinery, both for winning the minerals, transporting the same, and final manufacture, to be provided. A very important item in such a scheme would be the export trade of coal to Madras, and even other ports in the south. It is unquestionable that the profit on such a trade would go far to reduce the cost of importing the Madras ore in the return vessels. Given these conditions, and given that the steel company absorbed the profits from the mining of the minerals to the final out-turn, and carried out the scheme with a sufficient capital and with honest, unselfish supervision, there is no doubt that remunerative success awaits the enterprise.

It may be calculated that the cost of pig iron manufactured would not exceed Rs.36 (45s.) per ton, and the cost of finished rails and finished plates are estimated at approximately Rs.71 and Rs.85, girders and sections being priced intermediately. During the year 1898 the average cost of imported rails was Rs.89 per ton. The average selling price of angle and Tee section steel was not less than Rs.6 per cwt.

A word may be said on the labour question. It is not pretended that the native of India as a workman can compare with a European. His strength is less, and in most cases his intelligence as a mechanic is inferior; but he has advantages which go far to compensate. He is industrious, sober, cheap, and not given to the vices of trades unionism. Labour-saving devices which make up for the want of strength and want of skill are desirable, and help to bring the native on a par with the European. It may be noted that all the operations required in manufacturing steel are already in successful operation in India. At the Barakar Ironworks the local ore is regularly made into pig, and for the past six years open-hearth steel has been regularly worked at the Government Ordnance Works near Calcutta, and more recently in the East Indian Railway Works at Jamalpore. Steel bars and sections of all kinds are rolled in an 18-inch mill in the Ordnance Works, and machinery and fittings of all kinds are made in increasing quantity at various establishments throughout India.

## *DISCUSSION.*

Mr. H. BAUERMAN said the two papers were very suggestive in character. They contained a large amount of information, but it was information of a class that could scarcely be discussed very minutely. Major Mahon stated the three districts in which iron was got in any quantity in India. The general relation of those three districts was very much the same as that of the Swedish districts, if Sweden were swung round on its centre so that its south end was brought up to its north. The great difficulty, he gathered from Major Mahon's paper, was the want of anything like fluxing material. When he was investigating this question for the Government of India some years ago, he found, in regard to the limestones, that India was in some respects very like Scandinavia. There was not much in Northern India that would give a sufficiently good blast-furnace fluxing-stone on a large scale. In regard to the Chanda district, if Chanda were nearer to the sea, he came to the conclusion, when he went into the matter for the Indian Government, that the best thing might be to send the fluxing limestone from England. In Kumaon, where there was some good limestone, the use of which had been suggested for iron smelting, he found that the natives required it for betel-chewing—it was an article of food, in fact, which it might have been inadvisable to divert to other uses.

Mr. R. PRICE-WILLIAMS regretted that some years ago, when he had had the pleasure of being accompanied by Mr. Syed Ali, he had not passed through some of the particular mineral regions described in the paper; but having reported upon some of the minerals in the Singareni district, he could entirely confirm what had been said with regard to the quality of the mineral there—particularly the coal. The author, however, spoke rather too modestly of the quality of the coal when he said that it was a little worse than the average of English coal. If the author meant English coal simply, then he was not right, but perhaps he would be if he included the Welsh coal. It was a very different class of coal geologically from ours, being of a much more recent origin.

Shamsul Ulama SYED ALI BILGRAMI, in reply, protested against Professor Bauerman's rather pessimistic views. The Professor was acquainted with those parts of India where limestones did not occur; but, as he had stated in his paper, it was within his own knowledge that there were very large quantities of limestones in close vicinity to the Singareni coal. The quantity of lime used for betel-chewing did not enter into the question of economics; besides, the natives of India preferred a lime made out of shells, as it was supposed to be of greater potency than mineral lime. Mr. Price-Williams was a very old friend of his. He (the speaker) knew the Welsh coal, and he had worked underground in several English coal districts—for example, in Wales and in Staffordshire. When he spoke of English coal in the paper, he meant the coal which was exported to Bombay, and which naturally was the very best produced in the country. He was still of the opinion that the Singareni coal was not quite of that quality.

## *CORRESPONDENCE.*

The RITTER CECIL VON SCHWARZ (Meuerville, near Algiers) sent the following contribution:—

With reference to Mr. Syed Ali's paper, as far as it refers to the erection of an ironworks in His Highness the Nizam's dominions, the description of the resources of his country, with reference to the quantity and quality of the principal raw materials, namely, iron ore and fuel as well as flux, is very attractive indeed; and if carried on properly, such an undertaking may turn out a prosperous investment. It is, however, not quite understood why His Highness the Nizam has not taken the matter up himself as yet.

Judging from my several years' practical experience in India, and in view of the numerous ignominious failures in trying to introduce the iron industry on modern principles in India, and the reasons why, described hereafter, the following practical hints to those who probably might have the intention of utilising the mineral wealth as described by Mr. Syed Ali may be useful.

1. A competent person, with theoretical and practical know-

ledge in the manufacture of pig iron, or malleable iron and steel, and at the same time with practical experience, if possible, in iron working in India, should first be deputed to the spot and requested to make out a "report on the financial prospects of iron and steel working in Hyderabad," giving a full and detailed account, not only on the quantity and quality of the raw materials, but also of the cost per ton delivered at the place chosen for the erection of the works. Also the cost of labour and that of general expenses should be ascertained, as well as any other expenses connected with the manufacture of iron and steel at that place. An approximate estimate, as detailed as possible, should then be made, based on the results of the above-mentioned inquiries, showing the cost of producing—

(*a*) One ton of grey pig iron for castings.
(*b*) „ white pig iron.
(*c*) „ cast iron sleepers (Denham-Olpherts as well as pot sleepers).
(*d*) „ cast iron pipes, &c.
(*e*) „ steel rails.
(*f*) „ rolled rails.
(*g*) „ bar iron.
(*h*) „ tempered castings.

These cost prices should be given per ton at the place of production, as well as in those places where they could advantageously compete with imported goods of the same description, thus showing the difference of the cost prices and the sale prices in these places.

The question, at what exact place the ironworks may best be erected, should be most carefully examined with reference to the cost of transport of raw materials and finished goods, vicinity of railways, canals, &c., and, what is very important in India, also with reference to the water supply. A good part of the failures in trying to introduce the iron industry into India were due to the fact that the place for the erection of the works which failed was not properly selected.

I may also here remark that the late "Bengal Iron Works Company," when erecting blast-furnaces and foundries near Barrakur (1873), neglected the question of water supply; consequently when the works were set going they could not get sufficient water from their wells during the dry season, and they had to erect an expensive pumping station and a 10-inch pipe water conduit nearly two miles long, from the Barrakur river to the works, costing about 200,000 rupees, which might have been nearly entirely saved if they had erected the works as close as possible to the river, which they were in no way prevented from doing. The report should also contain an estimate of the cost of erecting an iron and steel works at the place selected for it, as well as all other information connected with the cost and financial prospects of such an undertaking.

2. In case the report were favourable, the assistance of the Government of India should be asked for, viz., the guarantee that the Government binds itself to take the products of the works to be erected for a certain number of years, and at a rate to be previously agreed upon; these rates being based on the prevailing market rates of imported goods at the place of destination, as per Government resolution, dated 5th August 1882, which decides that "the requirements of the Government State Railways and other Government works and undertakings (bridges, water works, &c.) should be covered by inland produce as far as possible, provided that quality and rates do not differ materially from those of imported goods."

3. The works should be commenced on a scale as small as practicable, but the arrangements should be made in such a way that future enlargements could be carried out without disturbing the work going on, and without injuring the system on which the erection of the works is based.

If possible grey pig iron for castings should first be made, as well as castings such as C. J. Railway sleepers, chairs, fencing posts, and spikes, pipes, &c. The manufacture of all these articles will easily be learnt by natives, and they will also find at once an easy sale in India. If this were in order, steelworks and rolling mills might be commenced.

4. European labour should be avoided as much as possible in India. It is very expensive and troublesome there. Judging from my nine years' experience of iron working in India, the natives of India, if properly handled, can be trained to almost any work required in the manufacture of iron and steel.

The failure of the Bengal Iron Works Company was principally due to the fact that they neglected this question. The Indian Iron Chrome and Steel Company erected, some forty years ago, ironworks in Southern India. They failed, however, after short operations, as the places where the works were erected were badly chosen, being too far from the sources of the raw materials, at the same time the means of communication having been very primitive and inadequate at the time.

The next attempt was made by Government. A blast-furnace and also a small rolling-mill were erected in Burwai, near Mhow, in Central India, by Mr. Milander, a Swede, under the control of the Political Agent at Mhow. Red iron ore, with 48–52 per cent. of iron, and charcoal were the raw material this undertaking was based upon; it proved, however, a failure. The blast-furnace was not sufficiently dried before starting, and not sufficiently hooped, consequently it burst shortly after being set at work and had to be laid cold.

In considering the subject of re-starting the furnace, it was again found that the question of supplying sufficient fuel could not be satisfactorily solved. The blast-furnace at Burwai was never re-started, and the work was abandoned. A third attempt was made later on in the Kumaon district, in the Central Provinces of India, where red iron ore with about 53 per cent of iron occurred. A private company erected blast-furnaces in three different places in the neighbourhood of Naini-Tal. These places were, however, badly selected, as the iron ore had to be brought to the furnaces from a great distance over hilly ground and rough roads by mules and goats; sometimes the furnaces had to be stopped, especially during the rainy season, for want of ore. Besides this, a proper supervision over the different blast-furnaces, which were several miles distant from each other, became almost impossible, and the company failed. Government took up matters, and a small charcoal blast-furnace, provided with Parry's cup and cone, hot-blast stoves, &c., was erected close to the iron ore. However, the works continually suffered from gas explosions and their consequences; and the pig iron, which should have been grey pig iron for castings, turned out to be mostly white, for which there was no use. The works were abandoned, as the question of supplying sufficient fuel could not be satisfactorily answered.

The Maharajah of Sirmur Nahan, not far from Simla, erected a charcoal blast-furnace on the top of a hill close to his residence. On inspecting the property, I reported that the place for the erection of the blast-furnace was very badly selected. The iron ore, magnetic ore with about 55 per cent. of iron, had to be brought on mules' backs over hilly ground and rough roads. One mule not bringing more than about 150 lbs. of ore at a time, the trip backwards and forwards required about five days. The charcoal, too, had to be brought from some distance, as the Maharajah would not allow the forests in the neighbourhood of his residence to be destroyed. The blast-furnace at Sirmur Nahan was never started.

The late King Theebaw of Upper Burmah, about fifteen years ago, was induced by some French engineers to erect an ironworks in Sagain on the Irrawadi, about seven or eight miles from Mandalay. A lot of machinery was brought out from Europe, and his Majesty took great pleasure and interest in supervising the erection. One day, however, when on his way to the works, the palankin broke down and his Majesty got badly hurt. The priests, who did not quite approve of his Majesty's keen interest in industrial enterprise, at once came to the conclusion that the accident was a bad omen, pointing out that the gods were against the erection of an ironworks so close to a holy pagoda, and that consequently they had sent a warning. Queen Supiala supported these views, and King Theebaw, being convinced that the priests were right, suddenly stopped the progress of the erection, and the whole came to a standstill.

When I was sent there by the Government in 1886, I found things in a depressed condition. There were two blast-furnaces, not quite finished, two blowing-engines, and three rolling-mills. All the buildings were without a roof, the machinery covered with rust and dirt, high grass growing all round, jackals in the steam-cylinders, &c. The brasses were everywhere taken out, and wherever they could not be got at easily, the respective castings, cylinder cover, &c., containing the metal sought for were simply smashed. When I asked the reason of this vandalism, I was told that the brasses were taken out in order to make cannon to fire at the English. However, the English were too quick for them, and Burmah was conquered before the cannon were finished. There were also eighteen egg-ended boilers, never used, but covered with rust. I could not advise Government to complete these works, as neither the fuel question nor the question of supplying sufficient suitable iron ore could be satisfactorily answered.

The late Bengal Iron Works Company started works in 1873 at Barrakur, near Raniganj, in Bengal. The place was well selected, as iron ore, with about 46 per cent. of iron, and coal of a suitable quality were close at hand. The place was also close to the East Indian Railway. The only drawbacks were that the coal was rather high in ash, 10 to 12½ per cent., and that it could not be freed from it by washing before coking. Also the flux (limestone) available in the neighbourhood contained about 10 per cent. of insoluble matter. The financial results of the first three years' working were deplorable. The blast-furnace got gobbed up twice, and had to be laid cold each time.

Many other difficulties were encountered, as the capital was insufficient, consequently debentures had to be taken up at a high percentage. The principal reason of the failure of the Bengal Ironworks Company, however, was the high cost of their European establishment. They had twenty-two Europeans employed, costing monthly over 5000 rupees, besides the general managers and the managing agents in Calcuttta, costing another 1600 to 2000 rupees a month. When Government took over these works in 1882 and put them under my charge, I commenced with a staff of nine Europeans only. Of these, four men could be dispensed with within about two years' time, and replaced by natives, so that my whole European staff consisted only of five persons including myself. Whilst the European staff of the late Bengal Ironworks Company, including managing agents, cost from 6600 to 7000 rupees a month, the cost under this head, while under Government, amounted to only 1700 rupees a month for the whole European establishment. There were no managing agents, and, moreover, there was no necessity for them. The Bengal Ironworks Company ceased operations in 1876, and the works were put up for auction by the debenture holders, but nobody made a bid, even with the comparatively small sum of 300,000 rupees asked for as a minimum by the debenture holders. Besides the above-mentioned attempts to introduce the iron industry on modern principles into India, some minor attempts in this direction were made in Warora (Central Provinces), in Beerbhoom (Bengal), and in the Nerbudda (Central Provinces), but all without success. Space will not permit me to describe these in detail. It was no wonder that, in face of all the failures, nobody had the courage to prosecute iron-working in India again, and the question did not arise from 1876, when the Bengal Ironworks closed operations, until 1882, when the Government purchased the Bengal Ironworks property and put them under my management for about eight and a half years. During this time the works yielded each year a reasonable profit, although the works were in no way protected, but had, on the contrary, to put up with several shortcomings and inconveniences which a private company would not have been exposed to, namely: (*a*) The Government Ironworks were prohibited from advertising their produce, as the Calcutta foundries seriously complained of Government competition. (*b*) Many orders given by Government were in excess of the requirements, and on account of mistakes in calculations, the castings made to order, but not accepted, had to be broken up and remelted, although they stood all the required tests, &c. No compensation, however, was given to the works for the loss thus sustained. (*c*) When the works were started by Government, it was understood that sufficient orders would be given for cast iron sleepers, in order to fully occupy the works for this article alone for several years to come, and orders were given to make arrangements accordingly. Consequently a large number of moulding boxes, patterns, &c., were made, the cost of which had to be distributed over the production. However, after hardly two years' working, the requirements of Government for cast iron sleepers were covered, and the high expenditure for the necessary arrangements was unjustified. Besides this, the works had to make other staple articles at great expense and trouble, as the natives had to be trained for making pipes, bridge piles, ornamental and other castings. (*d*) Government paid the Barrakur Ironworks lower rates for the articles supplied them than it would have cost them to bring out from England or from anywhere else.

Not only was the whole cost of management and supervision charged against the profits of the works, but they had also to pay the cost of the accountant establishment, as well as 10 per cent. depreciation on machinery and furnaces, and 5 per cent. depreciation on buildings, which, as a rule, is not charged by Government works. Government refused the outlay for new machinery, and I had to work with the obsolete arrangements left by the late Bengal Ironworks Company, after they had been lying idle for more than six years. Notwithstanding all these troubles, hindrances, and unnecessary expenses, the works yielded a profit, as may be seen from the reports by the Government accountant.

These results were only possible by exercising strict economy in every direction, especially with reference to the low cost of superintendence and the employment of cheap native labour. They were also only possible owing to the highly efficient control over the works by Colonel G. F. E. S. Neill on behalf of the Government. From this it may also appear that Mr. Syed Ali's statement, that "the experiment of manufacturing iron on a large scale under the auspices of the Government had proved unsuccessful," is, at least with reference to the Barrakur Ironworks, not correct.

Moreover, his remark that, as regards Government, the cost of supervision is too great, is not correct considering that the whole European establishment of the Barrakur Ironworks when under Government amounted, as mentioned before, to 1700 rupees only, whilst when under the management of the Bengal Ironworks Company it amounted to from 6600 to 7000 rupees a month, or more than four times as much. It may also correctly be assumed that the Barrakur Ironworks, when they were sold by Government to a private company in 1889, must have been in a better condition than they were at the time when Government purchased them from the late Bengal Ironworks Company, otherwise the new private company would certainly not have paid some 470,000 rupees (as far as I know) for these works, which were previously put up for auction for 300,000 rupees but without any bid being made.

In his paper Mr. Syed Ali gives some information with regard to the method employed in making cast steel in Hyderabad, but he is, I think, too superficial in his description of this most interesting old process.

The following is a brief repetition of a description of this process which I discovered in some old records. That cast steel was made in India can be traced back to more than 2500 years. In the tombs of Wurri-Goan in Central India, which are about 2400 years old, fragments of weapons made of Indian cast steel were found. The smelting process was carried on in flowerpot-shaped crucibles made of fireclay kneaded well with cow-hair and oil, then dried and baked. Each crucible was provided with a bell-shaped cover having a small opening on the top to be closed with a stopper made of fireclay. A bit of glass slag was put on the bottom of the crucible, after which it was filled up to two-thirds with a mixture of magnetic sand and laterite, then covered with leaves, as described by Mr. Syed Ali, and mixed with some charcoal powder, the latter acting as a reducing and carburising ingredient. The crucible was then placed on an underlayer consisting of a disc-like bit of fireclay, the cover with the stopper put on, and the whole buried in a heap of charcoal. A gradually increasing heat was now kept up for from about eighteen to twenty hours with four bellows when the melting commenced. The master controlled this process most carefully by lifting the stopper of the crucible cover and examining from time to time the contents, at the same time stirring the liquid mass to make it homogeneous. As soon as the proper degree of liquid condition was reached, which moment was carefully controlled, the bellows were stopped and the crucible with its contents allowed to cool down slowly. The crucible was then broken and a cake of steel of about 3½ to 4 lbs. in weight obtained. The cake of steel was, however, much too hard, and in order to reduce its hardness to the proper degree it was subjected to a kind of tempering process. After the cake was carefully cleaned from adhering slag, &c., it was dipped into a mixture of iron ore and manganese ore powder with clay-water, then dried and exposed to a light red heat. This tempering process was repeated until the master, by means of chisel and hammer, was convinced that the steel had the exact correct degree of hardness. It was then called "Kurs," and was sold to Persian merchants at the rate of one to one and a half rupees per seer (about 2 lbs.), who transported this material on mules' backs to Damascus, thus furnishing the principal material for the celebrated Damascus blades of the Middle Ages. The excellent quality of this material has never since been reached, and those who are acquainted with the manufacture of crucible cast steel will also understand the reason why. It is well known that the repeated melting of iron or steel makes the material brittle ("short"), though it may be absolutely free from phosphorus or any other noxious substance, as the melting always injures the connection of the molecules of the iron or steel; in fact, the less melting the better the quality. Now crucible cast steel, as a rule, is made of a mixture of wrought iron and steel scraps of different descriptions, already melted at least once or twice, whilst the natives used iron ore as a raw material. The natives were also most anxious that their cast steel, after having reached the proper degree of liquid condition, should not be kept in this condition any longer than absolutely necessary. By the old native process the molten steel was allowed to cool down slowly in the crucible, whilst with our process the molten steel is cast into cast iron moulds, which always cause a more or less sudden cooling down, which is not advantageous to the quality of the material. It is well known by every manufacturer of crucible cast steel how difficult it is sometimes to get the exact degree of hardness in the steel to suit certain purposes, especially with reference to steel for cutting tool blades, &c. With the ordinary process endeavours are made to reach the required degree of hardness by selecting such raw materials as, on an average, have the required contents of carbon in order to correspond with the required degree of hardness as far as possible. The natives with their process reached this degree by introducing into their cast steel an excess of carbon and by taking this excess gradually away afterwards by means of the slow tempering process, having it thus completely in their power to attain the exact degree, by interrupting this decarburising process exactly at the proper time in order to get a cast steel of a quality exactly suitable for the purpose.

The wrought iron pillar at Kutub, near Delhi, the large iron girders at Puri, the ornamental gates at Shumnath, the 24-foot wrought iron gun at Nurwur, &c., are also worthy monuments of native art of bygone times. How they were made with the primitive appliances they had at that time (the Kutub pillar weighs about ten tons and was made 1800 years ago, is totally inexplicable.

Mr. H. G. TURNER wrote that Major Mahon had very kindly placed at his disposal a report upon the manufacture of iron and steel in India, of which his paper was a brief epitome. The report was a valuable contribution to the project in view of establishing ironworks in India. Major Mahon divided his subject into chapters, dealing successively with the questions of India's fuel, iron ores, limestones, coke obtainable from Indian coal, site of the proposed works, trade, nature of output, and cost of out-turn. The most important of these questions was that of the fuel, for it was on that point that all previous attempts were wrecked in the endeavour to establish an iron industry in India, or rather in the Madras Presidency. Major Mahon had gone into the question in great detail, his observations and conclusions having been drawn from experiments on coking Indian coal, which were personally conducted by him during the years 1898–99. He had arrived at the opinion that certain coals, such as the Giridh and the Jheriah coals would furnish good metallurgical coke if properly washed and treated, either in beehive or retort ovens, as might prove most suitable. This point was of the highest possible importance, but, as Major Mahon had truly remarked, our information could not be placed on an unassailable basis until his opinion had been established by trial on a large scale in India. Major Mahon did not say how such trial was to be effected. Possibly he deemed that a matter beyond the scope of his paper—one to be solved by the money of the man of enterprise. But therein lay the difficulty. Where was such a capitalist to be found? The project would involve the expenditure of a very large sum of money, which might or might not be entirely sunk. It was doubtful whether the money would be subscribed by the public to a joint-stock enterprise. It was hopeless to expect any kind of guarantee from Government. For these reasons the question suggested itself whether it would not be better to commence with a fuel which could involve no possibility of failure, even though that fuel were far in excess of the cost of Indian fuel. It would be interesting to calculate what it would cost to ship Durham coal, washed and ready for the coke-oven, from England to India. The coal might be coked in retort-ovens at the site of the proposed works, the by-products sold, and by that means the resulting coke might be put into the blast-furnace at a cost which would not be prohibitive. Before the recent rise in the price of Durham coking coal, and allowing 5s. per ton of coke to be saved by the sale of the by-products, a calculation was made that the coke would cost 25s. a ton at the furnaces. Experiments would then be made as to the amount of Indian coal that could be mixed with the Durham coal; doubtless that would in time work out to great economy. Meanwhile there would be no difficulty in assuring the public that good pig would inevitably be produced; and ore, the most important element in success, would be established beyond all range of doubt. With regard to the iron ore, Major Mahon was assured that the Salem ore, concentrated as Mr. Heath concentrated it by simply sifting it by hand and wind, and also by magnetic concentration, as was now practised with similar ores in Sweden, would yield as good an ore as any to be found in use in any provinces in England or America, or on the Continent.

The evidence which Major Mahon had collected for that opinion seemed to admit of no adverse criticism. Nevertheless, in view, again, of the necessity of putting every point on as firm a basis as possible to satisfy the investor that this was no visionary project, it would be essential to procure from India a quantity of Salem ore, ship it to Sweden, and there pass it through concentration, and then smelt it with Durham coke. A sufficient quantity of ore for the burden of the furnace must be the measure of the cargo.

It might be mentioned that efforts were recently made to induce the Government of India to undertake the slight cost which that essential preliminary undertaking entailed; but for some reason that authority was unable to sanction the measure. Presuming that the refusal was based on a reluctance to assist private enterprise with public money, it was now possible to reopen that experimental measure by assuring the adventurers who might undertake its cost that they would be confirmed in the concession of the deposits of iron ore at Kanjamalai, in the Salem district, in the event of their trial of the ore being successful.

An indefeasible title to this deposit for sixty years would give shareholders an assurance of security for their investment; but to make the title contingent on any stipulation which was not within the control of shareholders would render abortive any attempt to get the public to subscribe to this scheme.

Major Mahon foresaw no difficulties which could not be surmounted in procuring limestone, but of course that must be looked into with great care, and concessions must be obtained for adequate deposits of the material. With regard to the site, Major Mahon adduced reasons for selecting a point on the seacoast of Bengal; but there did not seem much to recommend that site in preference to the sea-coast of Madras. The question would probably be decided by the directors of the company that might be formed to undertake the project.

His (Mr Turner's) brief notice of Major Mahon's excellent report could not be concluded without thanking him for the graceful tribute he had paid to the upright and enterprising originator of the iron industry in South India. Mr. Heath's portrait, which Major Mahon published in the title-page of his report, showed him to have been a man of thoughtful and intellectual mien, and the history of his enterprise and of his misfortunes showed that his memory was well worthy of the eulogy passed on him by their much respected Past-President, Sir Lowthian Bell. The Madras Civil Service owed Sir Lowthian Bell an expression of gratitude for having enshrined the name of Josiah Marshall Heath in the pages of the Journal of the Iron and Steel Institute.

The PRESIDENT asked the meeting to offer hearty thanks to the author of this most interesting paper on the iron industry in the territory of His Highness the Nizam. He also asked that a cordial vote of thanks be given to Major Mahon.

The votes of thanks were carried unanimously, and the meeting was adjourned until August 16, when the following paper was read:—

# PRACTICAL MICROSCOPIC ANALYSIS FOR USE IN THE STEEL INDUSTRIES, WITH AN INTRODUCTION TO A SYSTEMATIC STUDY OF SOFT AND DEAD SOFT STEEL.

By C. H. RIDSDALE, F.I.C., F.C.S.

## SECTION I.—INTRODUCTORY REMARKS.

THE structure and microscopical examination of steel is a subject on which a good deal has been said during the last few years, and it may seem to many of you that an apology is needed in again bringing it forward, but I must plead in extenuation :—

### REASON FOR BRINGING SUBJECT FORWARD.

*First,* that the subject, being comparatively new, is perhaps entitled in its earlier stages to have a good deal of attention drawn to it.

*Second,* that, valuable and interesting as many of the communications and discussions have been, I trust I may not be misunderstood if I say that they have been so chiefly either from a *general,* or else from a *purely scientific* point of view.

For instance, although the question of the various hardening theories has concentrated interest on subjects the study of which must lead to practical results, to many members it may not seem of *immediate* practical value, and no doubt whilst the numerous papers and discussions on this and other questions have been going on, the thought has arisen in their minds, " Of what *practical* value is the microscope to us *to-day?* "

The present paper will, I trust, be found to be essentially of a *practical* nature, and in some degree to answer the above question (or to be the means of eliciting an answer to it), as it will be looked at mainly from the steel makers' and users' point of view. The exact position may perhaps be shown more clearly by, in the first place, quoting a little from our own experience, and this may be of benefit to others who feel themselves similarly situated.

### OUR EXPERIENCE.

Although we had used the microscope in our laboratory for some years, it had, so far as steel samples were concerned, been chiefly in connection with what Mr. Osmond terms "pathological" questions, such as to verify soundness, or to examine unusual fractures of test pieces, and, on the whole, in a desultory way.

But, particularly during the last two or three years, in view of the growing interest in microscopy, and feeling that we must be thoroughly up to date in this matter, the question was presented strongly to my mind whether it was not desirable to go *more fully* into the microscopic examination of steel.

One thing was certain, we could not afford to follow up matters of *purely scientific* interest on the off-chance of their *ultimately* leading to valuable results, however alluring that course might be.

Works laboratories are not kept up for such purposes, but to yield results of *immediate practical* value. If the microscope was going to do this, it was a duty to the firm to press it into service; if not, it had no place with us for regular daily use, as, if the work was to be undertaken systematically, and to any material extent, it seemed likely it would involve an appreciable amount of labour and cost, and therefore the utility must be commensurate with this.

It did not seem that this would be the case, or indeed that any useful purpose would be gained by merely following up researches on the lines hitherto followed, or preparing specimens which were simply interesting from a scientific point of view.

On the whole, it seemed likely that it could be turned to account, but then the question arose: *how* was it to be made of practical use to us; in short, *what should we examine for?* The microscopic analysis of steel was a new thing, and there was no recognised system of tests. All the data had to be got, and the system devised.

In order to settle this question, a preliminary investigation up to a certain point seemed not only justified, but to be the only course to see if the daily use of the microscope was feasible on practical lines.

### DIRECTIONS OF PROBABLE USEFULNESS AND CONDITIONS TO BE MET.

As to the direction in which it might be made useful, suppose, for instance, a case arose in which steel at some stage, whilst it was being worked up, differed from its normal behaviour, and the chemical analysis showed nothing to account for the abnormal results obtained.

Now, we most of us have our own ideas as to the causes of any behaviour out of the common which material exhibits, and there are several directions in such cases in which it seemed probable that microscopy might afford light to verify or disprove the correctness of these ideas; but there arose another difficulty.

It might be quite possible to satisfy one's self, or to prepare a record of researches which would be listened to indulgently by the members of some institution such as this, but how far would the evidence adduced from such researches be accepted as satisfactory by the parties most interested, in many cases the consumers, when a difference of opinion existed as to the cause of any such unusual behaviour of material?

Naturally, they would also have opinions of their own, and these would tend to lean in their own favour.

Here was a tribunal where all the evidence must bear the most thorough sifting, with certainly no favour.

At the same time, I believe that where there is evidence of honesty of purpose, viz. an endeavour to get real light, almost every one will accept evidence, whether given by a so-called independent man or not. Men actually engaged in steel manufacture certainly possess some advantages (such as opportunities for observation) over independent men not engaged in manufacture, and therefore much of the investigation done will naturally be by them.

Clearly, however, in microscopic examinations, particularly when conducted by manufacturers, the indications on the strength of which conclusions are based, if they are to be of much practical use, should be of such a nature as not only to be apparent and to carry conviction to men not specially trained in microscopy, but also such as can be placed permanently on record.

These conditions are of course difficult to meet, particularly as with regard to the latter it is impossible to reproduce appearances by photography with anything like the clearness they are seen under the microscope.

As a set-off, however, there is the advantage in comparing samples with standards of not having to trust to memory, but being able to make careful and deliberate comparisons of the two side by side.

## REASONS FOR DEALING WITH *SOFT* STEEL.

A good deal of attention has been given to the microscopical examination of *hard* (tool) steel, and to medium grades, and much has already been published thereon, but so far, with the exception of Mr. Stead's able paper last autumn dealing with rectangular brittleness, very little has been said of the great and important subject of *constructional*, or soft steel, containing from about 0·1 per cent. to 0·16 per cent. carbon, and down to the very softest, containing 0·03 per cent. carbon. Yet there is no steel more liable to mistreatment, because no steel is used for a larger variety of purposes, and put in a partially worked-up state into a greater number of hands of all degrees of experience.

It is subjected to all kinds of treatment, and often successive treatments, of the precise nature of which, or the requirements expected of it when finished, very little information generally is given to the maker. Further, such treatment is not usually regulated with consideration for the material itself, but with a view to the minimum trouble and cost of product. On the whole it is wonderful how well it stands such usage, and how very few complaints are heard.

## EXACTIONS OF CONSUMERS OF SOFT STEEL.

And here let me remark incidentally that there is no such thing as a "best for all purposes steel."

For instance, it is impossible that a steel shall be the very best for welding, and at the same time the softest; or simultaneously for forgings and for rivets; or for electrical conductivity and for turning purposes; or for cold rolling and pickling, and also to show the greatest number of twists, with great elongation and low tensile strain.

Yet it is not uncommon for such opposite requirements to be specified, or steel to be bought without any indication for the purpose for which it is intended, and expected to give the *best* results for all of these requirements.

It would be much to the benefit of both the user and maker if the fullest particulars were always given both as to the ultimate purpose and the treatment the material would have to undergo in the intermediate processes.

This is one direction in which the study of effects of different kinds of *known* treatment on steel should be of value, another is the detection of what treatment pieces of steel of *unknown* history have undergone.

## COLLECTION AND VERIFICATION OF DATA NECESSARY.

No doubt a good many isolated facts bearing on the subject are already known, and some investigations have been published from time to time, but it is most important they should be collected and classified, widely discussed, and such as have been repeatedly verified fully recognised, together with the limitations of their applicability, and that such as are not correct be expunged.

Again, certain modes of treatment are liable to be assumed to give the same result, and in some cases may do so, but in forming the foundations of a system, where we require absolute facts, we must not take this for granted; as, for instance, steel heated to

1. Normal heat, and steel heated to
2. *Higher* than normal heat, or to
3. Normal heat for *longer* than normal time,

Provided work in such cases is continued down to a low red heat.

Similarly,

1. Steel of normal behaviour reheated, and
2. Steel of abnormal behaviour reheated, and which by reheating has had its toughness and softness restored, although till

this was done, whilst chemically soft and good, it was mechanically hard or brittle.

It is something if we only establish that they *are* similar, and may be regarded as such in future, or if not, wherein the difference lies.

Having for many years taken the greatest interest in and studied closely the effects of various kinds of treatment on steel, particularly soft steel, chiefly by methods other than the microscope, and in May 1898 brought before you some matter of this nature, as it bore somewhat on what I have now to bring before you, I trust I may remind you of some of the points.

## SOME OF THE POINTS PREVIOUSLY VERIFIED.

1. That good normal steel, or steel of the very purest quality, which was heated for a *short time* (three to five minutes) to a *high temperature* (near to welding but not to burning) and allowed to cool very slowly, developed large grains and became very brittle, or more properly *weak* or *rotten*, breaking generally with the first blow, with little or no deflection. The grains were generally so large that micro-photographs were unnecessary.

2. That the same steel treated in the same way throughout, except that it was *chilled*, showed almost the same degree of weakness, the chilling not having been able to sufficiently break up the structure to restore toughness.

3. That the same steel heated for a *long time* (say 3½ hours) at a quite *normal* and what is generally considered *harmless* reheating temperature,* and either allowed to *cool slowly* or *chilled*, showed the same properties.

4. That reheating to cherry redness (900° C. or over), whether allowed to cool slowly or chilled, restored the toughness in steel which had become brittle from any of the above causes. Special stress was laid on the reheating being *rapid.* †

5. That the restoration of toughness was *due to the breaking*

---

*** Mr. Stead has shown in his paper given at the same meeting in May 1898 that similar changes as far as the grain is concerned, but not accompanied by as much brittleness, are produced by very long heating (say 48 hours) at a low red temperature.**

**† He has also shown, in his paper given in the autumn of 1898, that (with more or less uncertainty) breaking up of the grain and corresponding restoration of toughness is brought about by slow reheating below 900° (say about 700°, viz. re-annealing).—*Journal*, 1898, No. II. p. 147, particularly last sentence.**

*up of the grain* (Figs. 30, 31), also billet (Fig. 29) when rolled to wire rods (Figs. 32, 33a, 33b), and when forged to bars (Figs. 26 and 27).

6. That steel of the same quality became very brittle if worked at a blue heat.

7. That reheating restored the toughness in steel rendered brittle by this means also.

The nature of the changes produced in the normal steel which first rendered it brittle by any of the above methods and then toughened it by reheating were all shown *as indicated by fracture* or mechanical test (as 26 and 27). I hope to bring before you in this paper the same as shown by the microscope, as I have considered that, since the samples referred to in that paper were prepared under known conditions, many of them would serve for examination for obtaining some of the data required for the purposes of the investigation described in the present paper, with the advantage that the effects of the treatment they have received can be compared both in their fracture and as seen through the microscope.

A fuller list of points touched on in this paper will be found further on.

## OUTLINE OF SCHEME ADOPTED FOR THE STUDY.

I propose, then, in the present paper to show you how I have sought to systematise the microscopic study of steel and render it available for everyday use in a busy laboratory, where commercial objects must ever predominate, so that it may be carried on with the minimum demands on time, or of specially expensive appliances, or other serious cost, and shall be of such value as to really have a *raison d'être*; also to give you briefly the lines followed, together with some of the results of our study of soft steel up to the present time.

Of course I cannot pretend to have more than suggested the outline for the study. To defer bringing these results before you till all that we have in view, even at present, was completed, might mean waiting for years, and there would then be too much matter for one paper. Besides, it is far better that other workers should come into the field at once.

An endeavour has been made to take the matter up at the point at which it may be considered as purely scientific, and to lay it out on practical lines. In view of the great desire that has been felt of late years to obtain universally recognised standard methods of ordinary analysis, it would be a great advantage if, from the outset, microscopic analysis could be worked out on definite and systematic lines which have met with general approval.

It is sought to show what can and cannot be done by it, and to obtain recognition for it, and for certain definite principles of examination, and also for the fact that *every piece of steel to a certain extent bears its own history recorded in it.*

To any one who has not studied the subject this will perhaps seem at first well-nigh impossible, seeing that not only do no two sections on examination show *exactly* the same appearance, but that the very same piece of steel can show such different appearances, according to the part the section is cut from, the way it is etched and illuminated, &c.

But on examining a *large number* of pieces of steel of a given type, it will be found that there are *certain characteristics common to all,* and it is these that we must first determine for that type.

Having ascertained these for a number of known or standard types, and familiarised ourselves with them, we can then begin making comparisons with other samples, the type of which we do not yet know, to see whether they have characteristics in common with any of the known types. Thus we evolve our rules for interpretation by successive *comparisons,* and hence it is all-important that the comparisons should be made *under strictly uniform conditions.*

We have seen, then, that the history can only be read by comparison with other samples which have undergone definite known treatment, viz. *standards.*

But for conclusions to be reliable, let me urge the necessity of *broad bases* from which to draw them.

There should be plenty of standards to compare with, which have undergone each particular kind of treatment, and these should *not be confined to any one make of steel.*

Indeed, it is questionable whether any trait should, with present experience, be accepted which is not met with in steels of all makes of that particular type, and the steels so far examined are by *eight well-known makers and four processes.*

Again, although of course in case of any steel behaving abnormally it is always desirable to obtain for comparison a piece of the same type of steel which has behaved normally, this in itself may not be sufficient. It is necessary, in the first place, to have ensured that all the conditions of sampling and preparation shall really be identical and not left to chance, and that there is nothing in the *composition* to account for the difference found.

Even then, without more experience than that gained by the comparison of an occasional pair of samples, it does not follow that any difference found is the cause for the different behaviour. Hence the importance of a constant and systematic study along definite lines.

All this of course involves dealing with a large number of samples, hence the necessity of quick preparation of sections and photographs, so simplified that assistants can perform this as readily and accurately as an ordinary analysis.

At present we have reached the stage that, from the time of receiving a sample, it can be sectioned, ground, etched, examined, photographed, and a finished print produced, in cases of urgency, in about two hours, which is generally a good deal sooner than the analysis for carbon, silicon, phosphorus, and manganese is performed, to say nothing of sulphur.

## SECTION II.—PROCEDURE.

### CLASSIFICATION.

The following is the system of classification on which we are working, which, it will be seen, whilst covering the most important groups, admits of expansion to any extent, as occasion arises:—

*Soft.*

CLASS I. *Steel of normal treatment and normal composition, i.e.* steel which has stood the normal processes satisfactorily and has given the normal commercial results, such as softness, toughness, soundness, or other qualities.

| Section. | No Further Treatment. | Further Treatment. | | | | |
|---|---|---|---|---|---|---|
| | Just as left after hot work finished. | Pickled. | Cold Worked, Rolled, Drawn, Stamped, &c. (generally pickled first). | Reheated after no Previous Treatment. | Reheated after Pickling or Cold Work. | Coated with Zinc, Tin, or Lead. |
| | Average “ maximum ” grains, approximate mean diameter. | | | | | |
| Billets, $1\frac{7}{8}$ in. to 4 in. | 2 in. ·0027 to ·0030 | Grain size not altered. | Grain broken up small on surface extending inward to varying extent according to amount and nature of work | If heated to cherry redness for a short time practically no change in size, except any odd large grains broken up smaller and homogeneity thus increased. If at higher temperature, for a long time grain grows larger according to length of time, and very rapidly for high temperatures, as welding. By excessive treatment in either respect they may grow to enormous size. | If to good cherry redness grains restored gradually to normal size. | No particular effect observed so far on size of grain. |
| Slabs, bars, and other large sections . . . | Grain follows most nearly in size the least dimension, though if mass retains heat, is somewhat greater than a square bar of size of least dimension | | | | | |
| Bars, forged, &c., 2 in. to 1 in. sq. . . . | $\frac{1}{2}$ in. round ·0005 to ·0008<br>$\frac{5}{8}$ in. square ·0007 to ·0010<br>$\frac{3}{4}$ in. round ·0008 to ·00125<br>(In rounds slightly smaller than in squares because less mass) | | | | | |
| Thick plate, $\frac{3}{8}$ in. to 1 in. . . . . . . . | $\frac{1}{2}$ in. ·0007 to ·0012<br>$\frac{5}{8}$ in. ·0008 to ·0013<br>(same applies largely as stated for slabs) | | | | | |
| Thin plate, $\frac{1}{8}$ in. to $\frac{3}{8}$ in. | $\frac{1}{12}$ in. ·0003, ·0005 | | | | | |
| Sheet and hoop up to $\frac{1}{8}$ in. thick . . . . | $\frac{1}{12}$ in. ·0003, ·0005<br>(pretty much as sheet) | | | | | |
| Rod and thick wire, up to $\frac{1}{8}$ in. and $\frac{1}{2}$ in. . | $\frac{1}{8}$ in. ·0003, ·0005<br>$\frac{1}{2}$ in. ·0005, ·0008 | | | | | |
| Thin wire, up to $\frac{1}{8}$ in. . | $\frac{1}{8}$ in. (see above) | | | | | |
| Other sections . . . | Controlled by area and mass | | | | | |

Then repeat as above for

Class II. Steel of *normal* treatment but *abnormal* composition, results known.

Class III. Steel of *known abnormal* treatment and normal composition, results known.

(*a*) "*Soaked*" *longer than usual* at *normal* temperature, and treated afterwards in various ways.

(*b*) Heated to *too high* temperature for *short* time, and *no* work, or work finished at too high a temperature.

(*c*) Heated to *too high* temperature for *short time*, but worked down to normal finishing temperature—low red heat.

(*d*) Work continued to too low a temperature (as blue-heat or cold).

Class IV. Steel of *known abnormal treatment* and *abnormal* composition, results known.

Class V. Steel of known *abnormal results*, treatment unknown.

(*a*) "Dry" opens at ends in rolling.

(*b*) "Red-short," ragged edges.

(*c*) "Hard;" poor elongation, twists, or bend tests, and high tensile strain.

(*d*) *Cold-short* or brittle, to a moderate extent.

(*e*) "*Rotten*," "breaks like pot."

(*f*) *Hollow*, seamy or laminated.

(*g*) *Blistered.*

Medium and hard steel can follow on exactly the same lines.

A summary of the main features of each of these classes will be found farther on.

It is of course out of the question in a paper like this, especially as it has already attained considerable length, to attempt to deal fully with all the points in each class or to show you photographs of the complete series, but, in order to make clear the way in which the changes brought about by these different treatments are studied, examples of a few of the sizes and of different makes of steel are shown. It is better to give a fair number of examples of one or two classes, to illustrate the chief characteristics running through them, than to give only one or two examples of each of a larger number.

Those classes have been considered in most detail which, either because they appear to have been least studied, or because the effects included in them are least easily traced back to the proper causes by other means, seem to be of most practical interest.

It will no doubt be obvious that, as far as possible, the sample to be examined and the standard with which it is compared should be not only of the same or similar make of steel, but of the same or similar section or sectional area; this is particularly so on account of the different size of grain in pieces of different area.

In the case of examination of steel which has behaved abnormally, the standard should if possible be another piece of the same maker's steel, worked up as nearly as the user can judge under the same conditions, but which has behaved *normally.*

## SIZE OF GRAIN.

It may prove a definite rule that in normal steel, for sections of such a size that they are finished below the critical temperature * but not below low red, under similar heat conditions (*i.e.* finished at the same or *pro rata* temperature and subjected to the same cooling influences), in steel of the same composition, the size of the grain is *inversely proportional to the sectional area,* and when it is not so this gives us an indication of the variation in the other conditions. So far, all the measurements taken closely confirm this, as shown in the accompanying diagram, in the smaller sizes the influence of decreased finishing temperature being more marked.

Therefore the *size of grain* in any piece of steel in relation to the sectional area of the piece is of very considerable importance.

It may be well to state here that by size of grain is meant the average "maximum size" of grain or the average size of grain of which a full sectional area is presented. A great many of what appear to be grains are only sections of *one part or corner* of the grains, and the more homogeneous and broken up the structure is the more this is so, whilst the more completely the grain has been able to form (or crystallise out) and the more regular it is, the larger and better defined the sectional areas are. For a strict comparison of the size of grain, therefore, it appears

---

* The temperature above which work does not reduce the size of grain, as described by Brinell.

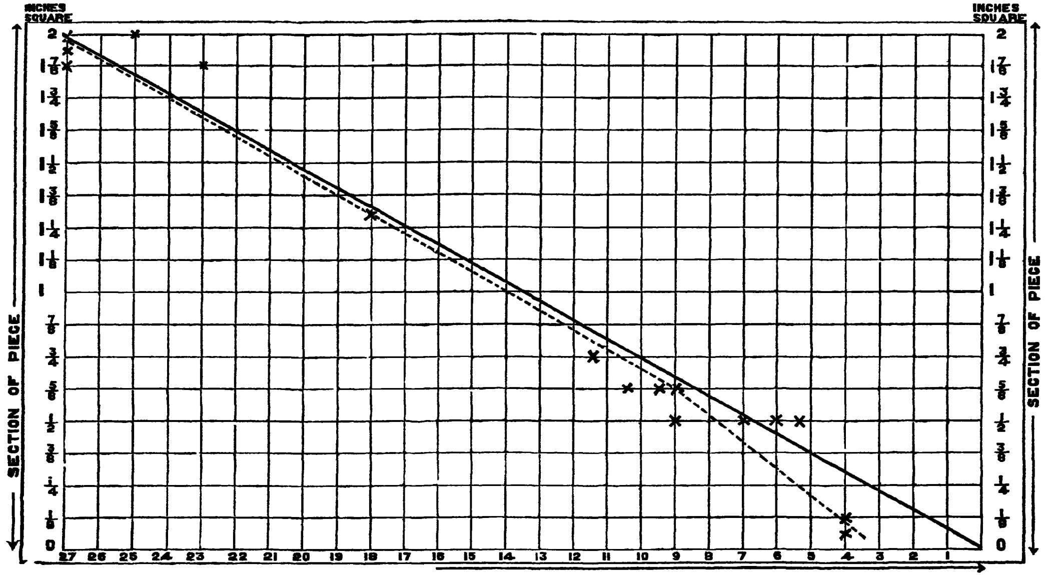
## SIZE OF GRAIN

*In various sized sections (bars).*

In *normal* soft steels of various makes. *Approximate* "average" maximum, mean diameter.

Size of grain as between extremes if assumed to vary *strictly inversely as sectional area* ————

Actual measurements made so far of size of grain. Each cross represents in many cases *several* separate samples - - - - - - -



**Actual measurements show that for smaller sections the grain size decreases more than *pro rata*, which might be expected as the finishing temperature also rapidly decreases, often finishing considerably below red heat.**

to be more accurate to measure only what appear to be full-sized sectional areas. Mr. Stead suggested this mode of procedure to me some time ago, and it has been followed throughout our investigation.

## SYSTEM OF EXAMINATION.

The following is the system of examination generally followed (1) under oblique light (Sorby's parabolic reflector); (2) vertical light (Sorby's angle 45° reflector), both for low powers only, as 20 to 50 dia.; also under vertical light (Beck's illuminator) for high powers, 100 to 1000 dia.

*Plain Polished.*—Examine for pathological defects such as: Cracks round edges, spilliness and shelliness, seams, laps, &c.; red-shortness, cracks round edge or in body; blow-holes and sponginess; slaggy matter, segregations; hollowness (piping); grain, whether shown in relief.

*Heated till Straw Colour.*—In some cases shows certain of the above more plainly, or enables better photographs to be taken.

*Light Etching as Iodine* (half saturated solution in alcohol).—All the foregoing under a different aspect; size of grain; disposition of grain and granular junctions; definition of grain. From the above are obtained the deductions immediately following.

*Deeper Etching, as Nitric Acid of Varying Strengths,* 10 *per cent. and* 20 *per cent.*—All the foregoing under a different aspect.

For the benefit of those who decide to prosecute this study, as it is to many new ground, to save them the labour of looking up the various works and papers on microscopy, photography, &c., and to assist them to decide on details of working, and particularly with a view *to unifying the system of examination,* it will perhaps be of use to give as an appendix particulars as to a number of points of practical manipulation, showing what, up to present date, we have found most feasible for everyday rapid work.

## SECTION III.—RESULTS OBTAINED.

### LEADING FEATURES OF CLASSES I. TO V.

*At low powers as 50 diameters, light etching.*

The following are some of the conclusions arrived at from the examination of a very large number of samples, and for which the evidence so far seems to be sufficient to warrant the indication given being put forward tentatively as definite tests, though it is to be hoped other workers will follow up the investigation and establish them more completely, or modify them as may be required.

CLASS I. *Normal Steel.*—Steel in which work has been continued to below critical temperature, viz. to from good red to low red. See also definition already given previously.

Shows what may be termed an "uninteresting" or regular structure which is almost homogeneous, the grains *small and often ill-defined.* The grains at the outer edge of the piece are at least as small and frequently *smaller* than at the centre, owing to the work on the outside. This is an important feature. They continue right up to the edge. On several of the photographs a narrow strip of white, due to light reflected on the slight bevel unavoidable in rapid practice, is seen, but is not at all to be confounded with the carbonless band in Class III., *a, b, c.* Still less is there any danger in practical observation of misconception on this account. As this paper is illustrating normal, everyday work, and not specially picked conditions, and the photographs are all taken from the running, it was thought better to show them as they really appear in practice.

CLASS II. *Steel of Normal Treatment but Abnormal Composition: Results known.*—What has already been said of Class I. applies in the main to this class also, for it should be remembered that we are not considering freaks with 1 to 4 per cent. of impurities, made simply as extremes for purposes of purely scientific interest, but *ordinary commercial* soft steels in which the carbon certainly will not exceed 0·20 per cent., nor the manganese 0·60 per cent., and which, if they contained as much as 0·10 per cent. of either silicon, sulphur, or phosphorus, would be regarded as of abnormal composition. Within these limits the grain size is *practically unaffected.* Compare Figs. 1 and 3, Plate III., also Figs. 26 and 27, Plate VI.; indeed, even with phosphorus (which particularly tends to give large grain), it will be seen from a comparison of Fig. 81, Plate XIII., with Fig. 1, normal steel, that although the former contains 0·16 per cent. of phosphorus, there is only a slight effect. It therefore may be safely concluded, should the grain differ much from that in normal steel, even though the composition is "abnormal" within the limits stated, that this must be attributed to other causes, such as the treatment whilst working, and *not* to the slightly increased impurities.

CLASS III., *a, b, c. Steel that has been Heated too long or to too high Temperature*, or finished too hot, but without *burning*, shows, according to the extent and manner in which this has been done, either an outer "carbonless" ring, or a ring of large grains, the grains being *larger* at the outside than further in, which is the reverse of what is found in normal steel, and is a sure sign of the above treatment.

This carbonless ring is often, with light etching, plainer to the eye than by the aid of the microscope. Sometimes, generally with deeper etching, it appears to the eye as a dark band.

At the edge sometimes the grains are quite separated, the junctions being wide open. Then it is approaching to "burnt" steel.

CLASS III., *d. Steel on which Work has been continued to too low a Temperature.*

(*a*) To blue heat, or through blue to straw.

(*b*) Steel worked cold.

(*a*) *Steel worked at or through blue heat.*—In order to properly understand what to look for, let us consider what takes place when steel is worked at various temperatures.

If worked only *above critical temperatures,* which for soft steel is from good yellow to white or welding heat, and allowed to

(1) *Cool slowly,* the size of grain is affected very little or not at all by the work, and when cold a section shows no flow-lines or signs of deformation, though if of small enough mass to be able to be

(2) *Chilled sufficiently rapidly*, such signs may be seen. For instance, a cross, in a small bar forged to low yellow heat and then suddenly chilled. In the first case, slow cooling from a high temperature allowed grains to arrange themselves and flow-lines to dissipate. The material being quite plastic at the temperature at which it was worked, the grains could move freely, hence their contact is good and the junctions sound; but if chilled before they have rearranged themselves, signs of the flow are left.

If worked to *below* the *critical* (viz. to a *normal*) *temperature*, say good red to low red, the grain becomes smaller, and well interlocked or homogeneous, and when cold flow-lines are more or less distinct, according to the temperature, mass, and rate of cooling. (See Fig. 4, Plate III. See also Fig. 85, Plate XIV.) In this case, too, the material being plastic at the temperature at which it was worked, the grain contact is good and the junctions sound.

*If worked through or to blue heat*, or subjected to shocks at this temperature, the effect tends in the same direction, but meets with a new limitation.

The material at this temperature appears to be in its condition of *minimum plasticity*.

If the blow or work is too light to distort the piece, it simply *sets up a state of strain* at the surface, which penetrates more or less deeply, according to the force exerted. Fig. 49, Plate IX., and Figs. 56 and 58, Plate X., are the nearest approaches shown to this.

Provided there is no actual distortion, however near the force has come to producing it, there can be no evidence visible through the microscope. The same will be true provided the distortion is not sufficient to yield flow-lines which can be distinctly recognised, although there may be a considerable state of internal strain or predisposition to rupture.

When the force is more powerful, notable distortion takes place, and its evidences, which take many varied forms, are clearly revealed by the microscope (see Plates IX., X., and XI.).

According to the nature of the work, whether light and rapid, as in hand-hammering, heavier and less rapid, as in steam-hammering (the work in these cases being shock), or whether strong and steadily applied, as in rolling, and according also to the mass of the piece subjected to it, so the visible effects vary, both in character and in the extent to which they penetrate the mass or are confined to the surface.

We have so far noticed the following indications, either or all of which may be present, and which are best seen by vertical illumination:—

1. Breaking up of the grain at the surface, penetrating more or less deeply.

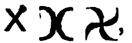
2. Loosening of the grain or opening of the granular junctions, and frequently actual rupture.

3. Flow-lines in various directions from the part where the force was applied, marking the direction in which the material has slipped, and indicating lines of weakness, the portions which have slipped being also in a strained or disturbed condition, these flow-lines culminating in

4. Cracks of all degrees.

Apart from the local indications 1 and 2, there is no special size of grain associated with steel which has had work at a blue heat, this being determined, as usual, by the mass of the piece and its previous history.

If the grain has been large before, it is still large except at the parts where work has broken it up, if it has taken effect in this way. This is the case if a piece of steel has been heated to above critical temperature, say to good yellow heat, and allowed to cool slowly without work on it till below red heat, and explains the increased brittleness found under these conditions and described by the author, p. 225, in the paper on "Brittleness in Soft Steel," read before this Institute, May 1898, the reason being, of course, that the grains, and hence the continuous junctions, are larger.

The flow-lines in square bars are frequently at an angle of 30° to 45° to the surface, and in such cases often take the form of a more or less regular and complete cross, , which may have straight or curved arms—apparently the harder the material at the time of forging, the straighter the arms of the crosses, whilst if softer they are more curved, also those in hand-hammered bars being less regular, and those in steam-hammered bars more regular, being generally more marked in proportion to the degree to which brittleness has been developed (see Figs. 61 to 68, Plate XI., and Fig. 85, Plate XIV.). In other shaped pieces the flow-lines are not so distinct or regular. The flow-lines, though sometimes visible before etching, are brought up much more clearly by it. They are frequently visible to the naked eye as dark markings on the surface. They are no doubt apparent on account of the different orientation of the crystals in the portions which have slipped, as compared with that of the adjoining portions. If by chance the orientation were the same in the adjoining portions, the flow-lines would be no longer apparent, which may perhaps account for the imperfection of parts of the crosses in certain cases.

Anton R. von Dormus * mentions some crosses visible to the naked eye in forged bars of hard (chisel) steel. He attributes the different appearance in that case to a difference between the carbon of the inner and outer portions, and reference is only made to them as bearing on the direction of flow in forged bars. Flow-lines, whether in the form of a cross or otherwise, are *not* in themselves a distinctive indication of work at a blue heat.

To sum up the causes of "blue-heat brittleness," there is no evidence so far of it being due to symmetrical arrangement of the crystals, or, indeed, to any particular structure *per se*, but to *strains*, and more or less complete *rupture* of a number of individual granular junctions or cleavages, developing sometimes into continuous cracks, all being due to *distortion* produced by work when the material is in its least plastic condition, *i.e.* at that particular temperature when, owing to its hard or brittle state, work is able to produce these effects.

Indeed, microscopic examination and other evidence brings out clearly the *vital fact* that whilst at a blue heat steel is in a condition of peculiar receptivity or sensitiveness to *retain* in permanent form (strains, cracks, &c.) the effects of shock or work. No doubt this *retention* of the effects (besides actual cracks formed at the time, which no subsequent treatment could remove) is largely due to there not being sufficient heat for the parts which are merely strained to readjust themselves whilst cooling, as is the case when work is finished at a red heat, and still more so when finished at a yellow heat.

---

* "*Weitere Studien über Schienenstahl.*" *Zeitschrift des Oesterreichischen Ingenieur und Architekten-Vereins*, vol. l. 1898, p. 635.

There can be no question as to the brittleness being *permanent.* Samples prepared eleven years ago, viz. in 1888, were recently broken, and were still as brittle as ever.

As further showing that the brittleness is not necessarily due merely to *surface* distortion or to cracks *actually developed,* but also to *state of strain* and *hard condition* which has equally been retained, a sample from which the outer $\frac{1}{16}$ inch was filed (thus removing any surface cracks), though it did not break without deflection as before, broke on bending through 40°, and was therefore not tough. The crosses going right through the pieces also show that the effects are more than superficial, whilst the cutting, filing, grinding, and polishing give abundant proof of the *greater hardness* right through.

The practical question as to what amount of shock or work at blue heat is necessary to cause brittleness is one which cannot be answered exactly, but there have been plenty of instances where in the case of plates the work and conditions they have gone through, together with subsequent vibration or shock, have been sufficient to cause fracture.

The question *why* steel is peculiarly sensitive at these temperatures still remains unanswered. But however interesting it might be to pursue the inquiry it is not of *practical* importance, it has not incidentally been revealed by the microscopic examination, and it is outside the scope of this paper.

(*b*) *Steel Worked Cold.*—The same general features are presented as in steel worked at blue heat, but for the same amount of work the effects of distortion are not apparent to so great an extent owing to the greater plasticity of the material at that temperature.

Provided the work is sufficiently severe, almost identical effect may be produced though there is not so much of the appearance of "loosening" of the individual grains.

The blue-heat worked bars, photographs of which are shown, were not perceptibly reduced in size, and the hammering was relatively light; even when steam hammered, the blows were as light as possible. The bar which was cold hammered, and of which Figs. 73 and 74, Plate XII., present an appearance almost identical with Fig. 52, Plate IX., blue-heat hammered, was reduced from ¾ in. square to ½ in. square (or to less than half its area) by cold hammering.

The flow in a cold sheared plate is also clearly visible, and shows the pull particularly at the last part of the cut. See Figs. 70 and 71, Plate XI.

Attention may here be drawn to a point of considerable practical importance which is by no means as widely recognised as it should be, viz. the *undoubted fact* that both surface cracks and hollowness in the mass can be developed in material at points where it was before *perfectly sound*, by work at too low a temperature.

This seems to be particularly the case with *forging*, where the work is applied in a succession of local shocks repeated at certain points, thus producing an accentuated flow or creep along corresponding lines, and a more or less symmetrical disposition of material. Indeed the Mannesmann Tube Process depends entirely for its success on the readiness with which, under certain conditions, even in hot material, unsoundness can be produced in the centre of sound steel.

Note also the increased tendency to lamination in plates and sheets, and to blistering in tinplates and cold rolled bright strips, even the "hot" work on which is often very near blue heat, and which also often undergo further cold rolling.

There can be no doubt that the surface and interior do not spread equally, the difference at times being so great as to cause rupture along the lines of flow, which is frequently revealed on pickling.

The author is quite aware that it is usual to attribute this wholly to blow-holes, but it does not follow that because certain sheets are sound, the steel from which they were made had no blow-holes. Blow-holes exist to a greater or less extent in *all* steel of *every make*, but the work the material undergoes closes them up, and it depends very largely on the conditions of further working whether or not they are reopened and manifested. What it is here sought to point out is that in a great number of instances where blisters appear these are *due to variations from the normal conditions, in the temperature of working up, in pickling*, &c., and it is these which have brought about an actual separation of the fibre which would not otherwise have occurred.

The fact remains that the same steel, which in tinplates, &c., would give blisters, in sections of greater mass (work on which is consequently finished at a higher temperature) does *not* yield blisters when pickled. Either a billet, or for that matter a blistered wire rod, would be a curiosity worthy of sending to the British Museum.

The fact is, distortion strains exist in *all* worked material at the time of working (though of course they are less the softer the material at the time of working), but when worked hot they are dissipated by slow cooling, and in most cases more or less fixed by chilling. They are also dissipated by reheating.

The same general characteristics as have been described for cold-worked soft steel, viz. the flow following the lines of force, have already been shown for hard steel by Mr. Stead * in his now well-known photographs of the effect of wear on a rail, tyre, and chisel. The causes are the same as in cold and blue-heat worked soft steel: work causing compression of the surface, hence flow, hence weakened cohesion of the mass affected.

Although there is perhaps, in the absence of knowledge as to the amount of work which a sample has undergone, no very distinct indication as to whether brittleness has been produced by work at blue heat or work whilst cold, in practice this is hardly likely to prove a difficulty, as the conditions of manufacture will generally be sufficiently well known, or even apparent from the piece itself.

Indeed, in seeking for the cause of brittleness in any particular instance, the evidence which the microscope affords as to blue or cold working may be rather of a negative character, viz. the *absence* of evidence of excessive or prolonged *heating*.

If the sample is thin and the brittleness not due to composition, weld-heating, soaking, or excessive oxidation, then it is necessarily due to blue or cold working, and which of these, as already stated, can generally be distinguished.

CLASS IV. *Steel of known Abnormal Treatment, and Abnormal Composition, results known.*—Just as Class II. in the main closely resembles Class I., so Class IV., broadly speaking, resembles Class III., only as fresh factors are introduced the results obtained are correspondingly varied.

---

* *Journal of the West of Scotland Iron and Steel Institute*, No. I. vol. iv. November 1896, "Micro-Mechanical Examination of Old Steel Rails and Tyres."

Class V. *Steel of known Abnormal Results, treatment unknown.*—Steel of this class should always be analysed, and its composition borne in mind when examining it microscopically, and special endeavour should be made to procure suitable standards, as referred to already.

The different features of one or other of the previous classes will no doubt be met with and readily identified.

(*a*) and (*b*). If the steel on analysis proves to have been of suitable composition for the purpose for which it has been used, faults of this class generally prove to be varieties of *burning*, but it would take too long to deal with this here, and as a good deal has already been published on the subject, and a number of examples shown by other writers, it is not proposed here to go into it to any length. The ordinary indications are frequently sufficiently unmistakable without the aid of a microscope, and it is generally only needed to determine whether, in the cases of certain sections, tears and cracks are due to pull of the rolls through improper draughting or feeding, or to red-shortness. The characteristics are those of Class III., (*a*), (*b*), (*c*), but intensified, according to the extent burnt. There is the carbonless ring or band along the edge penetrating more or less deeply, accompanied by oxide cracks and fissures between the grains, these latter generally being quite plain when the section is examined in the polished state before etching.

(*c*), (*d*), and (*e*) generally prove to be due to the same causes as in Class III., (*a*), (*b*), (*c*), or (*d*), if steel has been of suitable composition for the purpose used.

(*f*) and (*g*) are mechanical defects which may easily be recognised, and the accompanying structure generally shows quite clearly whether these have been initial defects present in the steel when supplied, or whether there has been anything in the subsequent treatment of the steel to account for them. As example see Figs. 51 and 52, Plate IX.; 57 and 59, Plate X., and Fig. 69, Plate XI.

One or two examples illustrating the identification of the treatment samples of Class V. have received, are shown.

Examination at higher powers gives more detail, whilst deeper etching gives a different aspect.

In conclusion, the whole object of the investigation described in the present paper has been to obtain information, deductions from which shall be of *practical* use, such as data either

(*a*) To *definitely* confirm what are generally accepted as correct conclusions, but for which such definite data were not published.

(*b*) To show how certain behaviour under mechanical or physical treatment is brought about, and hence, by inference, how to avoid such behaviour if objectionable.

(*c*) As to the indications that steel is likely to show certain behaviour, beyond what can be judged by composition.

The time has now arrived when it should be well recognised that composition only indicates such well-defined effects as are generally understood *without certain narrow limits* of treatment, which are termed "*normal.*" The moment we get outside these limits, the effect of the *treatment* far outweighs that of the *composition.* Often so-called "normal" treatment in manufacturing processes is really abnormal, *i.e.* the effect of the treatment has outweighed that of the composition.

Makers of steel can only control the composition, which is often the least powerful factor, so it is most important that, since competition frequently leads users to more or less abnormal or unsuitable treatment, they should understand what it does.

Whilst it is objectionable to dogmatise—and in advancing any views at all there is always a risk of being afterwards proved to have drawn wrong conclusions, especially if a subject be looked at too narrowly, as exceptions can always be found—still, if progress is to be made, definite statements must be formulated as starting-points.

The outcome so far of the investigations made may perhaps be best gathered from an

## INDEX TO THE MAIN PRACTICAL POINTS TOUCHED ON, AND CONCLUSIONS DEDUCED IN THE PRESENT AND FORMER PAPER.

(*Where Photographs are referred to, see also accompanying Remarks in Key to Plates.*)

1. *Size of grain and general features of Normal Steel of different sections.*

See Figs. 1, 3, 4, Plate III.; Fig. 17, Plate V.; Figs. 25, 28, to 33, Plate VI. Remarks, pp. 111, 113, and 116. Diagram, p. 114.

2. *Size of grain and general features of Steel of Abnormal* **Composition.**

A good measure of the effect of increased impurities on the size of the grain is to compare the centre of pieces in which segregation has occurred with the outside, as in this case the conditions of work, heating, &c., are identical (see Fig. 2, Plate III.; Figs. 26 and 27, Plate VI.; Fig. 81, Plate XIII.; also remarks, pp. 116, 117). Professor Arnold * has shown that even with impurities in about ten times as great proportion as usually occur in practice they do *not*, by prolonged heating, rediffuse into the mass. The writer has shown † that segregated impurities do not harden or otherwise adversely affect the mechanical properties of the steel, so that from a practical point of view segregation is a good thing, as it concentrates impurities where they are least hurtful, and as when once there they cannot re-enter the mass, they are for practical purposes eliminated from the steel.

3. *Size of grain and general features of Steel of Abnormal* **Treatment.**

See Figs. 6, 7, 8, 9, Plate III.; the whole of Plate IV.; Figs. 18 to 24, Plate V.; the whole of Plates VII., VIII., IX., X. Remarks, pp. 117–123.

For effect of prolonged heating at low red heat, see Mr. Stead's paper on "Brittleness Produced in Soft Steel by Annealing," *Journal of the Iron and Steel Institute*, vol. ii. 1898.

---

* "The Diffusion of Elements in Iron," Arnold and M'William, *Journal of the Iron and Steel Institute*, 1899, No. I. p. 85.

† Discussion, Baron von Jüptner's paper, "The Influence of Phosphorus on Cold-Shortness," *Ibid.* 1897, No I. pp. 241-242.

4. *Effect of* **Rapid** *Reheating—Far more effectual than chilling for breaking up grain structure and rendering material tough—Chilling steels on which work is finished at too high a temperature, or which have undergone other treatment described for Class III.* (a), (b), *or* (c), *is not sufficient to restore its good qualities.*

*For effect of rapid reheating—*

*On Normal Steel,* see point 5.

*On Abnormally Treated Steel,* see Figs. 7 and 9, as compared with Fig. 6, Plate III.

*For effect of rapid reheating plus work* **above** *critical point—*

*On Abnormally Treated Steel,* see Figs. 75, 76, and 79, Plate XIII., as compared with Fig. 6, Plate III.

*For effect of rapid reheating plus work* **below** *critical point—*

*On Abnormally Treated Steel,* see Figs. 77, 78, Plate XIII., as compared with Fig. 6, Plate III.

5. *Steel, Normal, reheated and cooled* **slowly** (compare 8).

See Fig. 5, Plate IV., as compared with Fig. 1, Plate III. Remarks, p. 107, point 4, also Key.

6. *Steel, Abnormal* **Composition,** *reheated and cooled slowly* (compare 9).

See remarks, first paragraph, point 2. See Fig. 8, as compared with Fig. 7, Plate III. Remarks, p. 138, to Fig. 8. See Key.

7. *Steel, Abnormal* **Treatment,** *reheated and cooled slowly.*

See Fig. 7, Plate III.

8. *Steel, Normal, reheated and chilled* (compare 5).

See Fig. 9, Plate III.

9. *Steel, Abnormal* **Composition,** *reheated and chilled* (compare 6).

The sample, Fig. 9, Plate III., was practically the same in the centre as at the outside, just as is the case with Fig. 8.

10. *Steel, Abnormal* **Treatment,** *reheated and chilled* (compare 7).

See Fig. 9, Plate III. See also Figs. 75, 77, and 79, Plate XIII.

11. *Effect of Chilling* v. *Cooling slowly*—

| | *Chilled.* | | *Cooled slowly.* |
|---|---|---|---|
| *Billet* at cherry red . . . | Fig. 9, | Plate III. | Fig. 7, Plate III. |
| *Forged bar* at cherry red . . | Fig. 75 and 79, | Plate XIII. | Fig. 76, Plate XIII. |
| ,, low red . . | Fig. 77, | Plate XIII. | Fig. 78, Plate XIII. |
| *Round ⅜-inch rod* at low red . | Fig. 12, | Plate IV. | Fig. 11, Plate IV. |
| ,, ,, . | Fig. 19, | Plate V. | Fig. 18, Plate V. |

12. *Steel Abnormally Treated, if worked at red heat, becomes practically Normal Steel.*

*Soaked too long.*—Figs. 11, 12, 15, and 16, Plate IV.

*Worked at blue* (only if no permanent cracks found).—Momentary reheating to redness restores toughness. See paper on "Brittleness in Soft Steel," May 1898, p. 222. Vide Plate I. in that paper.

*Worked cold* (only if no permanent cracks found).—Is well known and recognised, as for instance annealing of cold rolled tin-plates before tinning, &c.

13. *Steels of different makes, but of the same class, e.g. Ordinary Soft, possess characteristics in common.*

See all normal steels of same or approximately same section, particularly Figs. 28 to 33, Plate VI.; also remarks on point 1. Indeed, the grain is *pro rata* practically the same size in all these steels, though of considerable variation in composition.

14. *Brittleness may be developed in any good sound Steel by Abnormal Conditions of Mechanical and Physical Treatment, the effects far outweighing ordinary Abnormal Composition.*

See Fig. 6, Plate III. Also, this is more or less accentuated in Figs. 13 and 14, Plate IV.; and Figs. 18–24, Plate V.; and very pronounced in the whole of Plates VII., VIII., IX., and X.

15. *How such Brittleness is brought about.*

The different stages of the transformation from tough to brittle steel are illustrated in the respective series of photographs.

In *prolonged or excessively heated* samples, the growth of the grains or carbonless band, then the gradual penetration of oxide cracks or loosening of the junctions. See particularly Figs. 19 and 23, Plate V.; Figs. 34, 37, Plate VII.; Figs. 45, 46, Plate VIII.

In *blue heat and cold-worked steel*, as described fully in sections dealing with this, pp. 117–123.

16. *Hollowness may be developed in any good sound Steel by Abnormal Conditions of Mechanical and Physical Treatment.*

Some of the same steel as Figs. 25, 26, 28, and 33 were prepared from showed this whilst preparing blue-heat worked samples. See also the blue-heat and cold-worked series, Plates IX., X., XI., and particularly Figs. 51, 52, Plate IX.; Fig. 57, Plate X.; Fig. 69, Plate XI.; and Figs. 73 and 74, Plate XII.

17. *Unsoundness to some extent is met with in all makes of Steel usually regarded as sound.*

Nearly every sample of normal steel examined shows this, though generally very slightly, and it was particularly observed in pieces from which Figs. 29, 30, 31, 32, from different makes, were prepared. The portions of the photograph shown, Fig. 29, exhibit this. All the others showed the same at another part of the photograph.

The list of characteristics so far stated is necessarily very incomplete, especially as it is considered better not to put forward any for which there are not already very good grounds.

With regard to judging of the probable previous treatment steel has received, which is perhaps the direction in which it may at first be most generally used for practical ends, although the microscope affords fuller and more delicate indications than fracture, yet the latter mode of testing is often more striking, and the readiness with which such tests can be conducted, and the force with which they appeal to those not specially trained in the appreciation of such evidence as the microscope affords (and such are many works managers and foremen), there will often be occasions when they will be considered more valuable for purposes of practical demonstration.

Certainly they may now be accepted with still greater confidence than formerly, in view of the very full confirmation they have received from the study of the same samples by the microscope, the degree in which the various indications correspond being very close indeed, and hence the points brought forward in my paper of May 1898 may be accepted without hesitation.

The classification system adopted will serve also as a key to the behaviour and practice which may be expected from samples subjected to treatment such as was there described.

It is due to my chief assistant, Mr. A. B. Marquand, and to other assistants, to acknowledge their invaluable help, and indeed nearly the whole of the preparation of sections and much of the photographic work referred to in this paper has been done by them.

# APPENDIX I.

## PRACTICAL MANIPULATION DETAILS.

### *Sampling.*

It is not practicable to section the whole area of large pieces, say over $\frac{5}{8}$ inch square, and in most cases a total area of $\frac{1}{4}$ inch to $\frac{3}{8}$ inch square is preferable. It is therefore important to follow a *fixed rule*, and always cut the section from one definite position, so as to be of value for comparison. This is more obvious as the grain may vary a good deal from the centre to the outside in sections of large area.* The section cut can of course be a *cross* section, or one parallel with the direction of rolling, or a section of the outside surface. For many purposes, including grain measurement, we prefer the cross section, and this may be sufficient, though in some cases the other sections are desirable.

The sketches will illustrate the general principle. In *billets* half the section, $\frac{3}{16}$ inch thick, is sliced off. Then the strip AB is cut, forming a section from opposite sides right across the centre; this is again cut in half, each half showing all the variations from centre to outside, and the centre of each half, *i.e.* the part midway between the centre and outside of the billet, is perhaps most truly representative of the whole. Strip A is polished on the face shown, thus being a *cross section*. Strip B is polished so as to give a section in the direction of rolling or *side elevation* of the section, and if desired C can be cut and polished to show a plan of the *surface*.

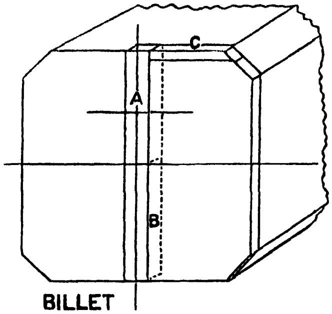
For *flats* the position most truly representative of the mass is along the line midway between the centre and outside as D, but whether the cross section be taken at this point or along the centre line as E, a V-shaped cut, having a face $\frac{3}{16}$ inch broad, will in most cases be sufficient, and less trouble than cutting off a full slice. The two ends of the section so cut will represent two outer sides.

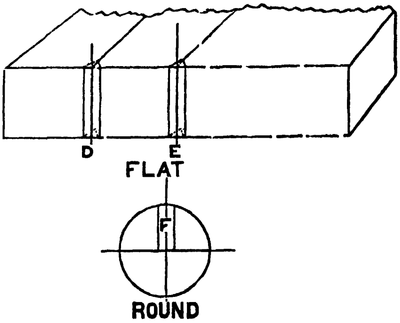
---

* Mr. Albert Sauveur drew attention to this in the case of rails in his paper on the "Microstructure of Steel," before the American Institute of Mining Engineers, *Transactions*, vol. xxii. 1893, p. 546.

From *rounds,* if only about $\frac{5}{8}$ inch diameter, a full slice is cut, but if larger than this, a half section is cut and then the piece marked F cut out of it.

For very small sections as wire, thin sheets, &c., it is convenient to fix a number together by forcing them tightly into a piece of bicycle or other steel tube, or binding with tin sheet, and filling up the interstices with fusible metal such as melts at below the boiling point of water—which low heat insures that there shall be no interference with the structure. A section is then sawn off the whole.





Sections are never cut too near to any distorted part, such as a sheared edge or fracture, since the grain arrangement is not normal in such a case.

## *Grinding.*

This is done substantially as already described by Mr. Stead and others. For most purposes we give the following treatment:—

Rough filing.
Fine filing.
Rough commercial emery cloth stretched on a board.
Fine emery cloth stretched on a board.
Finer specially prepared emery paper on disc in Mr. Stead's polishing machine.
Diamantine on cloth on disc in Mr. Stead's polishing machine.

Rouge on wash-leather on disc in Mr. Stead's polishing machine.

Rouge on wetted parchment stretched on glass for very fine work. For most purposes exceedingly fine polish free from all scratches is not necessary.

### *Mounting.*

The sections are mounted by means of a microtome, with a very little ordinary modelling material (a sort of grease and clay mixture which always remains plastic).*

### *Protecting.*

If now or at any later stage the surface requires protection from corrosion, a drop of solution of resin in benzol is put on it. This, when required, can be at once removed by benzol and a clean soft rag.* Definition of grains, especially by oblique illumination, is often lost on removal of this, but it is the best method we know of so far. In spite of this, if samples are kept in a place that is at all damp, streaks of rust work under it.

### *Etching.*

For determination of size and definition of the grain, a solution of iodine in alcohol is generally most suitable, and the operation can be conducted under the microscope, and being watched whilst in progress, can be judged to a nicety. Usually one to two minutes is sufficient. The section is then washed with a few drops of methylated spirit, and generally rubbed with the finger to avoid spurious markings, then pure alcohol, and dried by rapid motion or heat; and generally it is rubbed with wash-leather. When finished it is so light that usually it can hardly be seen with the naked eye.

Etching with acid, on account of the bubbles and acid spray and vapours given off, is far more likely to injure the reflector, so this is not generally done under the microscope. Sections are then washed with water, lime water, water again, methylated spirit, and pure alcohol.

---

* Method suggested by Mr. Stead. See also his two papers, *Journal of the Iron and Steel Institute*, 1894, No. I., "Methods of Preparing Polished Surfaces on Iron and Steel for Micro-Examination;" 1897, No. I., "Micro Accessories for Metallographers."

Care must in all cases be taken that the etching fluid evenly and simultaneously covers the whole area of the section, otherwise various markings and other differences may result, which will give rise to misleading conclusions, especially as the relative rate of attack is sometimes of considerable significance.

## *Illumination.*

For moderate powers, such as can be obtained from a 1-inch objective, oblique illumination with Sorby's parabolic reflector gives a more general and detailed, or what may be termed "perspective" view, and in most cases is useful for grain measurements, showing the grain outlines sufficiently clearly.

Sorby's 45° reflector gives a "plan" or view of the grain outlines, illumination being vertical, and in some cases is preferable. For instance, flow lines which are scarcely noticeable under oblique illumination may be easily apparent with this.

In both the above cases it is better to have previously removed the glass disc of the Beck's illuminator, if this is also fitted on the microscope.

Beck's illuminator is chiefly useful for higher powers, as $\frac{1}{4}$-inch and $\frac{1}{8}$-inch objectives—for which it is indispensable—with 1-inch objectives, and a low-power eyepiece, as No. 1 or 2; this latter form of illuminator does not give a full field. It gives vertical illumination.

An incandescent gaslight, with a reflector behind and condensers in front, will be found a most satisfactory source of light.

## *Examination.*

Just as care is taken that the section cut shall represent as nearly as possible the whole of the piece from which it is cut, so equal care should be exercised not only that the whole section cut should be examined, but that the part of it selected for the photograph should be *strictly representative* of it.

It is important to keep this ever before one's mind, and not to be tempted into keeping as a record a part which is *not* strictly representative, simply because it is curious or interesting.

It is always well to make notes at the time of examination, as even the best photographs cannot show up the various characteristics as plainly as they appear to the eye.

Though it is useful for comparative results as far as possible always to keep a record at one fixed magnification (say, for instance, 50 diameters), it is better, in addition to this, to examine it at two or three different powers, say at least with different eyepieces and frequently different objectives. An examination of the image on a clear-glass focussing screen with an eyepiece will, however, give a still greater magnification.

## *Photographing.*

*Focussing.*—This is by no means always easy, owing to the great dispersion of light in higher powers.

For locating the extent of the field, so as to find the position of any part of it, such as the edge of the piece, on an exact position on the plate; also, for giving a correct idea as to how the photograph will appear, a finely ground glass disc is very useful. With low powers, say up to 50 diameters, focussing can be clearly and sharply done on it.

To ensure very sharp focussing, a clear-glass screen and examination with a low-power eyepiece is preferable. Indeed, for very high powers this is practically indispensable.

We generally examine with both, especially since the latter, as already mentioned, gives a very good idea of the appearance under increased magnification.

The clear-glass is not indispensable, and has the disadvantage of being easily dulled by the breath, but it is more exact than merely holding the eyepiece in the right position.

We prefer, for comparative work, to always have the focussing screen at a fixed distance from the eyepiece, viz. 9 inches. This saves complication, especially in grain measurements.

*Dryplates.*—For cheapness and handiness, we use ¼ plates of a moderately rapid make.

*Exposure.*—From 35 to 110 diameters, 5 to 12 minutes with oblique light, and 4 to 9 minutes with the 45° reflector, is usually sufficient; whilst for 300 diameters, 35 minutes with vertical light. Higher powers *pro rata.*

If prints are wanted very quickly, immediately the negative is rinsed it can be steeped in methylated spirit, and dried within 2 to 5 minutes. *After* taking the prints required, the usual washing can be done before storage.

*Printing.*—It has been considered best to be independent of daylight, and use bromide paper, a *slow* type giving density being preferred. Enamelled paper gives better detail than matt surface.

The exposure varies from 2 to 5 seconds at 2 feet from an incandescent gas-light, but for weak or dense negatives can be humoured to a large extent. With care, it is almost impossible to have a failure.

The print should be washed for at least one hour, though in urgent cases, where durability is of secondary consideration, less will suffice, and in this case, too, it can (like the negatives) be dried with the use of spirit.

*Mounting.*—" Slip-in " mounts and books will be found most convenient.

*Average Time, in Urgent Cases.*

| | Minutes. | | Minutes. |
|---|---|---|---|
| Sawing off section according to size of piece from which cut | 1 | to | 5 |
| Grinding and polishing | 15 | to | 30 |
| Polish examination | 2 | to | 3 |
| Etching and washing | 3 | to | 5 |
| Examination and photographing | 7 | to | 10 |
| Developing, fixing, rinsing, and drying negative | 15 | to | 15 |
| Printing | 2 | to | 2 |
| Developing, fixing, and rinsing print | 15 | to | 20 |
| Washing and drying in spirit | 60 | to | 60 |
| Total | 120 | to | 150 |
| | 2 hours. | | 2½ hours. |

*Grain Measurement and Comparison.*—For practical purposes, the exact measurement of the outline of all the grains with a planimeter, as described by Mr. Sauveur,* is too tedious.

The best general idea of the relative structure of the standard and the piece being examined is obtained by comparing the photographs of each *on exactly the same scale.* This is why uniform treatment of standards and samples at all points throughout has been advocated strongly, and if they are selected to correspond with each other within reasonable limits, the range of effects produced by uniform treatment is not too great for reliance to be placed on the results of comparison.

---

* *Transactions of the American Institute of Mining Engineers*, vol. xxii., 1893, p. 546.

For record it is desirable, as nearly as may be, to give a numerical value to the grain size, and this can be judged very readily and with a fair degree of accuracy by measuring the grains with scales drawn with Indian ink on clear glass, the surface of which has been prepared with retouching medium.

Micrometer scales are first photographed at the same magnification as the samples, the clear-glass scales being prepared from these.

*Summing up and Recording Results, &c.*—This should be carefully done as the examination proceeds, and will be found of great assistance in reproducing any given effect at a future time with precision, say, for instance, a duplicate print.

The records generally made, besides general remarks as to the appearance, opinion as to what the sample indicates, and anything else of note, are as follows:—

Number.
Etching medium.
Etching time.
Objective.
Eye-piece.
Magnification.
Illumination used.
Part of section photographed (whether outside or centre, &c.).
Exposure.
Print exposure.

[APPENDIX II.

# APPENDIX II.

## THROUGHOUT ALL THE PLATES, EXCEPT WHERE OTHERWISE STATED, THE SECTIONS HAVE BEEN ETCHED WITH IODINE, AND MAGNIFIED 49 DIAMETERS. OBLIQUE ILLUMINATION (SORBY'S PARABOLIC ILLUMINATOR), PLATES I. TO VI., ALSO XI. AND XII., AND VERTICAL ILLUMINATION IN PLATES VII. TO X.

## NORMALLY TREATED STEEL, SUBJECTED TO KNOWN ABNORMAL TREATMENT (BILLET).

*All from Pieces of the same Billet, treated as described below.*

(See pp. 227-231, "Brittleness in Soft Steel," *Journal of the Iron and Steel Institute*, vol. i. 1898.)

| Paper of May 1898. | | Present Paper. | | | | Remarks. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Position. | How Cut. | Composition. | | | | | | |
| Fig. No. | Plate No. | Consecutive No. Fig. | PLATE III. | | | | *C.* | *Si.* | *S.* | *P.* | *Mn.* | |
| 22 and 25 | III. | 1 | Billet 2 × 2 in. NORMAL steel, NORMALLY treated | Edge | Cross section | Edge . . | ·05 | nil | ... | ·05 | ... | Note homogenous structure, and size of grain practically equal from centre to edges. Although owing to segregation phosphorus twice as high at centre as outside. Evidently within such limits no perceptible effect on size of grain. |
| 22 and 25 | " | 2 | " same piece " " | Midway | " | *Average* | ·05 | nil | ... | ·055 | ·36 | |
| 22 and 25 | " | 3 | " " " | Centre | " | Centre . | ·05 | nil | ... | ·10 | ... | |
| | | | | | | No. 2 is etched slightly deeper than No. 1, and No. 3 slightly deeper than No. 2. Compare effect of etching. | | | | | | |
| 22 and 25 | " | 4 | " " " | Midway | Longitudinal | The longitudinal sections of all three positions are practically identical with the one shown. Note fibrous structure developed by rolling. These sections also confirm points noted for cross sections. | | | | | | |
| 23 and 24 | " | 6 | Another piece same billet NORMAL steel, ABNORMALLY treated | Near edge | Cross section | Heated 3½ hours in ingot furnace; cooled slowly. Note *enormous growth of grain.* This had penetrated almost throughout the billet, and grains at centre were much the same size as at edge. | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 29 | III. | 7 | Another piece same billet | NORMAL steel, ABNORMALLY treated | Edge | Cross section | Reheated rapidly to cherry red in blacksmith's fire; cooled slowly. Note powerful breaking-up effect of rapid reheating, *bringing the piece back almost to normal structure.* This effect has penetrated to the centre. |
| 29 | ,, | 8 | ,, | ,, ,, | Centre | ,, | Reheated rapidly to cherry red in blacksmith's fire; cooled slowly. This is really steel of Abnormal composition. See analysis given for Fig. 3. |
| 31 | ,, | 9 | ,, | ,, ,, | Edge | ,, | Reheated rapidly to cherry red in blacksmith's fire; chilled in water. The same breaking-up effect of rapid reheating is shown here. Being low-carbon steel, and of fair mass, there is very little difference from the sample which was cooled slowly. |

## PLATE IV.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 28 | III. | 5 | Another piece of same 2×2 in. billet, as FIG. 6. | NORMAL steel, ABNORMALLY treated | Edge | Cross section | Subjected to NORMAL annealing, *i.e.* reheated rapidly to cherry redness, and cooled slowly. The structure is substantially the same as in the normal billet. |

### Effect of Rapid Reheating + Work at Different Temperatures, &c.

*Prepared from Billet, Fig. 6, Large Grains when Cold, but rapidly reheated and Structure thereby broken up, rolled down.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 32 | V. | 10 | Rod ⅜ in. diameter | NORMAL steel, NORMALLY treated | Edge | Cross section | Reheated rapidly in wire-mill furnace, finished at low yellow, cooled in air. Rapid reheating and fairly rapid cooling has broken up the large grain. |
| 33*b* * | ,, | 11 | | ,, ,, | ,, | ,, | Reheated rapidly in wire-mill furnace, finished at low red, cooled in air. The same to a still greater extent owing to the work at lower temperature. |
| 33*a* * | ,, | 12 | ,, | ,, ,, | ,, | ,, | Reheated rapidly in wire-mill furnace, finished at low red, chilled in water. Shows rather more the effect of chilling than Fig. 9, probably because of smaller section, hence chilling more rapid. |

### Effect of Work at Different Temperatures, &c.—Influence of Rapid Reheating Eliminated.

*Prepared from Billet same Material as Fig.* 1, *but treated as Fig.* 6, *so as to have Structure of Fig.* 6 *at time of rolling,* i.e. not *broken up by reheating.*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 35 * | V. | 13 | Rod ⅜ in. diameter | NORMAL steel, ABNORMALLY treated | Edge | Cross section | Rolled, finished at yellow heat, cooled in air | The grain somewhat larger throughout than in the case of Figs. 10, 11, and 12, as might be expected, owing to absence of breaking-up effect of rapid reheating of the billet. |
| 35 1 *hr.** | ,, | 14 | ,, | ,, ,, | ,, | ,, | Rolled, finished at yellow heat, chilled in water | |
| 34*b* * | ,, | 15 | ,, | ,, | ,, | ,, | Rolled, finished at low red heat, cooled in air | |
| 34*a* * | ,, | 16 | Rough ½ in. sq. | ,, ,, | ,, | ,, | Rolled, finished at low red heat, chilled in water | |

* Parts of the identical piece which was cut in two just before the final treatment.

## STEELS OF VARIOUS MAKES, DIFFERENT SECTIONS, TREATED **ABNORMALLY.**

### THE SAME STEELS AS ON PLATE VI., HEATED FOR FIVE MINUTES JUST BELOW WELDING HEAT, AND ALLOWED TO COOL SLOWLY.

*Allowed to Cool from above the Critical Temperature without Work.*

For sections and make BEFORE abnormal treatment, see particulars, Plate VI.

| Paper of May 1898. | | Present Paper. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fig. No. | Plate No. | Consecutive No. Fig. | | *C.* | *Si.* | *S.* | *P.* | *Mn.* | Analysis represents | Remarks. |
| | | | | PLATE VII. | | | | | | |
| No. 3 Maker | VIII. | 34 | Prepared from Fig. 30 . . | ·105 | ·038 | ·047 | ·055 | ·46 | Whole piece. | Note carbonless band, with large grains, continuing far into the piece; only towards the centre do the grains become smaller. |
| | ,, | 35 | ,, ,, ,, ,, . . | | | | | | | |
| No. 4 Maker | ,, | 36 | ,, ,, ,, 31 . . | ·110 | ·020 | ·057 | ·060 | ·38 | ,, | Note the same as above. The photograph by vertical light shows this more distinctly. |
| | ,, | 37 | ,, ,, ,, ,, . . | | | | | | | |
| No. 5 Maker | ,, | 38 | ,, ,, ,, 32 . . | ·095 | ·130 | ·041 | ·055 | ·046 | ,, | Note the same as in Figs. 34 to 37. |
| | ,, | 39 | ,, ,, ,, ,, . . | | | | | | | |
| No. 2 Maker C. ·135 | ,, | 40 | ,, ,, ,, 25 . . . | ·135 | ·055 | ·044 | ·06 | ·35 | ,, | The outer portion has hardly reached the stage of a carbonless band, the grains are larger towards the edge, and the perlite grains in process of being decarburised. Note the broadening junctions. |
| No. 2 Maker C. ·18 | ,, | 41 | ,, ,, ,, 26 . . . | ·28 | ·103 | ·082 | ·11 | | Centre. | Compare this with Figs. 42 and 43. |
| | | | | PLATE VIII. | | | | | | |
| ,, | ,, | 42 | ,, ,, ,, 26 . . . | ·15<br>·28 | ·010<br>·103 | ·027<br>·082 | ·05<br>·11 | | Edge.<br>Centre. | The vertical light shows the formation of the carbonless band very distinctly. |
| ,, | ,, | 43 | ,, ,, ,, 27 . . . | ·18 | ·046 | ·041 | ·060 | ·45 | Whole piece. | |
| | ,, | 44 | ,, ,, ,, 28 . . . | ·13 | ·028 | ·055 | ·069 | ·69 | ,, | Note carbonless band, which covers the whole photograph, not reaching the grain structure in the centre. |
| 44 | VI. | 45 | ,, ,, ,, 33 . . . | ·12 | nil. | ·02 | ·02 | ·12 | ,, | These two photographs not only show the carbonless band, but very large grains in the transition from this to the smaller grains in the centre. |
| No. 1 Maker | VIII. | 46 | ,, ,, ,, 29 . . . | ·135 | ·021 | ·041 | ·060 | ·42 | | |

## PLATE IX.

## THE SAME STEELS AS ON PLATE IV., HAMMERED FOR TWO OR THREE MINUTES AT BLUE HEAT.

*Work continued to too low Temperature.*

---

*Vertical Illumination.*

| | | | | Composition of Whole Piece. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *C.* | *Si.* | *S.* | *P.* | *Mn.* | | |
| No. 2 Maker C. ·135 | VIII. | 47 | Prepared from Normal Steel Fig. 25 . . | ·135 | ·055 | ·044 | ·06 | ·35 | Hand hammered | Note small grain where blow has struck, and flow at angle to the surface. |
| No. 2 Maker C. ·18 | ,, | 48 | ,, ,, ,, 26 and ,, 27 . | ·18 | ·046 | ·041 | ·06 | ·45 | ,, | Note same as in 47, also loosened grain. |
| — | — | 49 | ,, ,, ,, 28 . . . | ·13 | ·028 | ·055 | ·069 | ·69 | ,, | Note same as in 47. |
| No. 1 Maker | ,, | 50 | ,, ,, ,, 29 . . . | ·135 | ·021 | ·041 | ·06 | ·42 | ,, | Corner showing change of direction of flow. |
| No. 2 Maker C. ·135 | ,,<br>,, | 51<br>52 | ,, ,, ,, 25 . .<br>,, ,, ,, 25 . . | ·135 | ·055 | ·044 | ·06 | ·35 | Steam hammered | Note greater effect of steam hammering in breaking up the grain small, also deeper penetration of this effect and lines of flow strained almost to rupture in 51, at angle of 45° to the surface. In 52, actual rupture has taken place in parts and commenced in others, being continued as lines of flow. |

## STEELS OF VARIOUS MAKES, DIFFERENT SECTIONS, TREATED **ABNORMALLY.**

### THE SAME STEELS AS NOS. 25–33, HAMMERED FOR TWO OR THREE MINUTES AT BLUE HEAT.

*Work continued to too low Temperature.*

---

*Vertical Illumination.*

## PLATE X.

| Paper of May 1898. | | Present Paper. | | Normal Steel. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Fig. No. | Plate No. | Consecutive No. Fig. | | Composition of Whole Piece. | | | | | | |
| | | | | C. | Si. | S. | P. | Mn. | | |
| No. 1 Maker | VIII. | 53 | Prepared from Fig. 29 | ·135 | ·021 | ·041 | ·060 | ·42 | Steam hammered | Further examples of flow at the corners and at another part, and of loosened grains in both. |
| ,, | ,, | 54 | ,, ,, ,, 29 | | | | | | ,, | |
| No. 3 Maker | ,, | 55 | ,, ,, ,, 30 | ·105 | ·038 | ·047 | ·055 | ·46 | Hand hammered | Note flow lines at an angle to the surface, nearly at point of rupture. |
| No. 4 Maker | ,, | 56 | ,, ,, ,, 31 | ·110 | ·020 | ·057 | ·060 | ·38 | ,, | The same effects as in 53 and 54, but less marked. |
| No. 5 Maker | ,, | 57 | ,, ,, ,, 32 | ·095 | ·030 | ·041 | ·055 | ·46 | ,, | The same effect as in 51. |
| ,, | ,, | 58 | ,, ,, ,, 32 | | | | | | ,, | The same effect as in 49, note too, faint flow lines at same angle to surface as in 57, but not so fully developed. |
| 5 Special | V. | 59 | ,, ,, ,, 33 | ·12 | nil | ·02 | ·02 | ·12 | ,, | Note crack extending downward from surface almost to bottom of photograph. |

## PLATE III.

### NORMALLY Treated Steel, subjected to KNOWN ABNORMAL Treatment. ALL from Pieces of the SAME Billet, Treated as described.

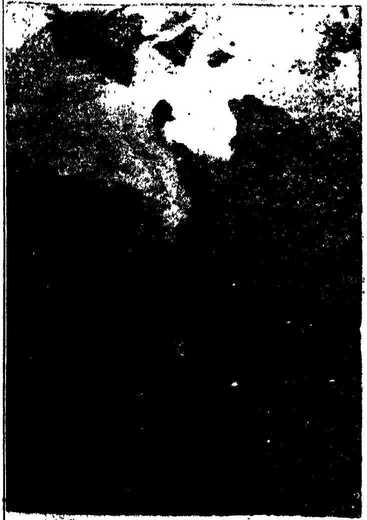
2″ Billet.

1

2

3

4



6

7

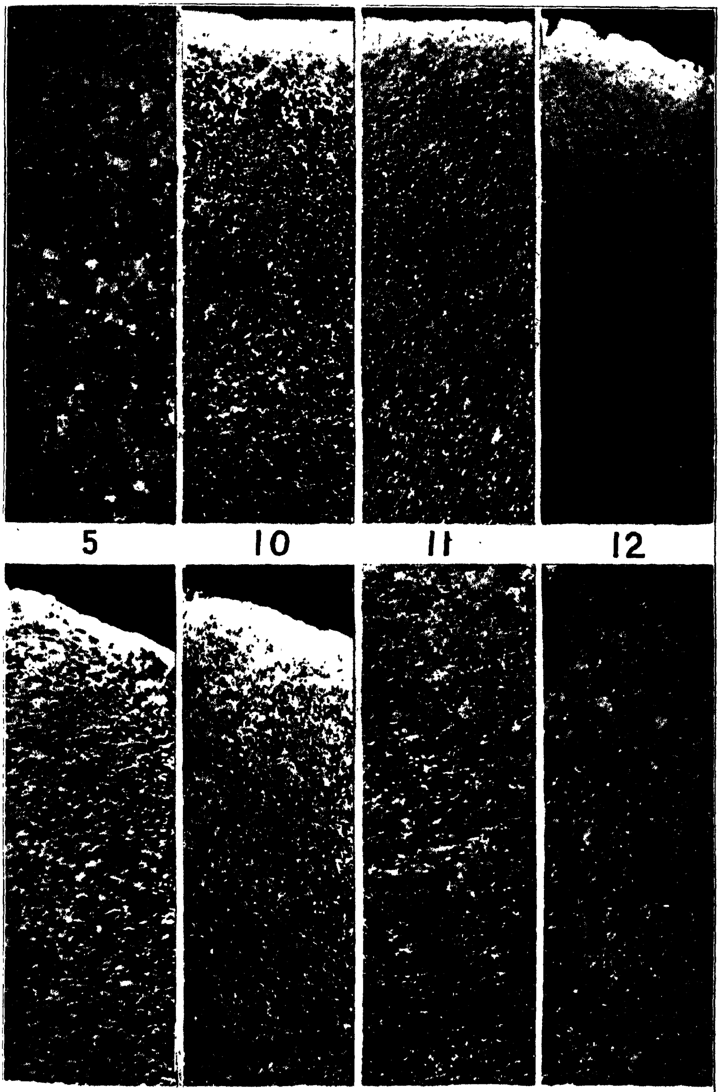
8

9

PLATE IV.

## NORMALLY Treated Steel, subjected to KNOWN ABNORMAL Treatment. ALL from Pieces of the SAME Billet, Treated as described.

2″ Billet, and Rods rolled from it.

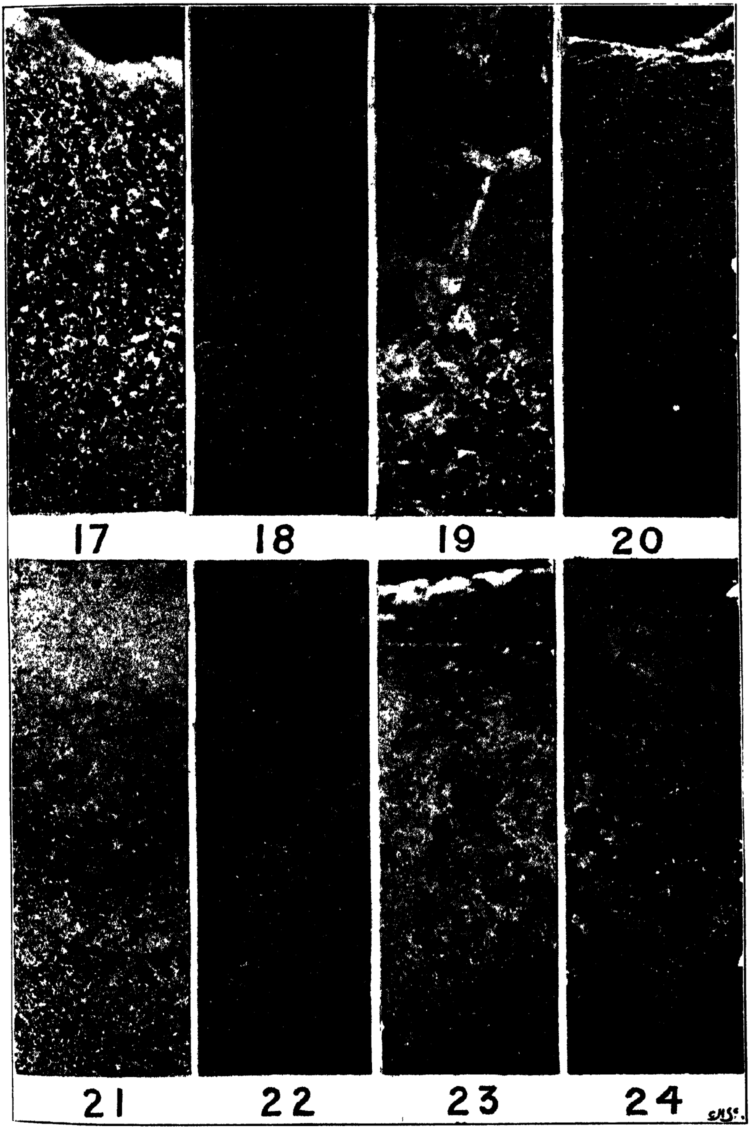


5 10 11 12

13 14 15 16

## NORMALLY Treated Steel, subjected to KNOWN ABNORMAL Treatment. ALL from Pieces of the SAME Rod, Treated as described.

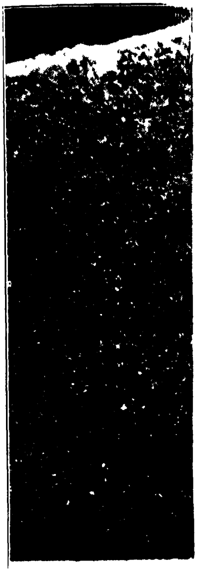
$\frac{3}{8}''$ dia. rod.



Carbonless rings practically structureless on outside. They appear quite as indistinct as this to the eye. The grain structure begins to appear

PLATE VI.

## Normal Steel of Various Makes, Different Sections.

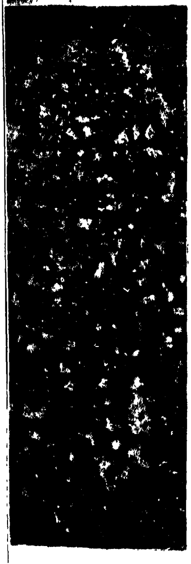


25

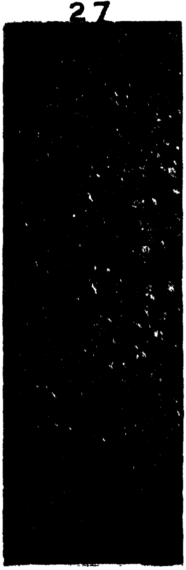
26
27

28

29

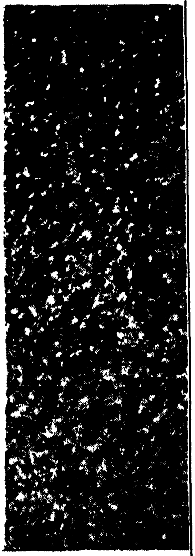


30



31

32



33

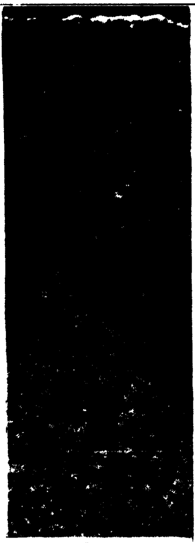
PLATE VII.

## Steel of Various Makes, Different Sections, Treated ABNORMALLY.

Work finished above Critical Temperature.

34

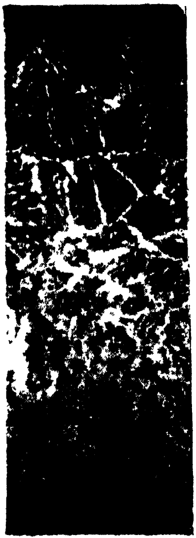
36



38

40

35



37v

39

41

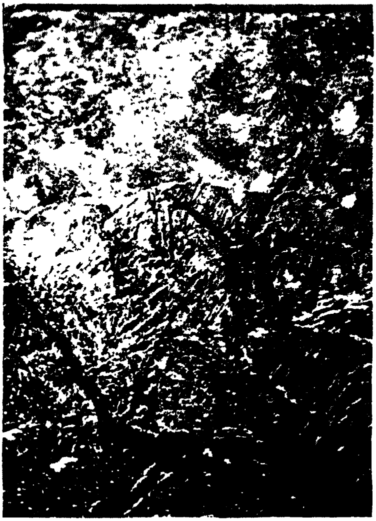
PLATE VIII.

## Steel of Various Makes, Different Sections, Treated ABNORMALLY.

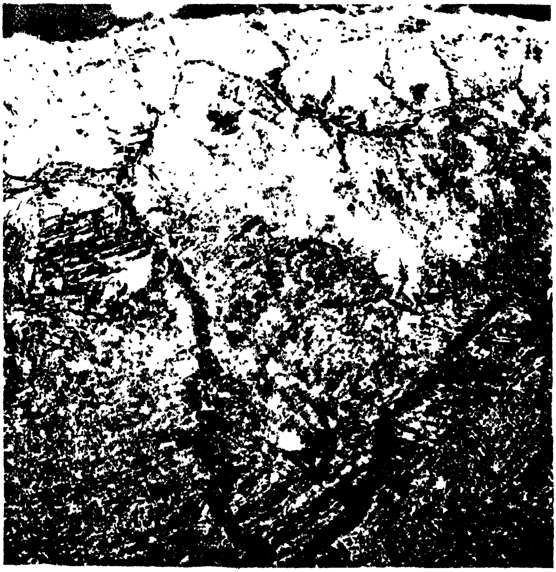
Work finished above Critical Temperature.

42.V
43.V

44



45.0



46.0

PLATE IX.

## Steel of Various Makes, Different Sections, Treated ABNORMALLY.

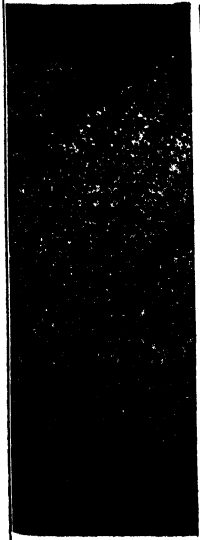
Work continued to too Low Temperature.

47

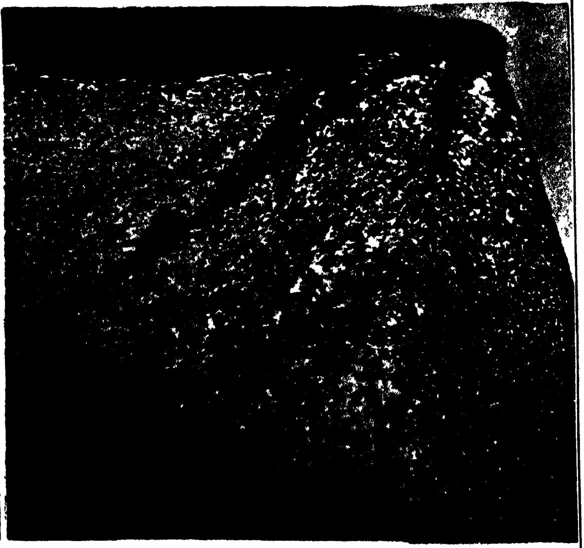
48

49

50



51

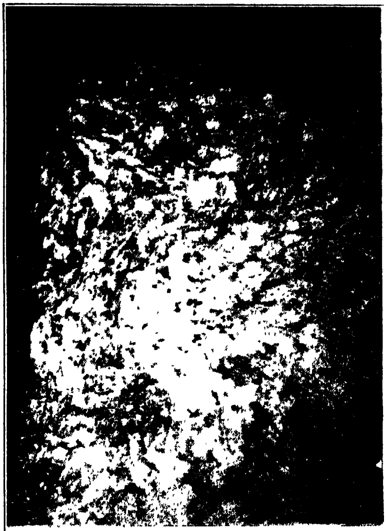


52

PLATE X.

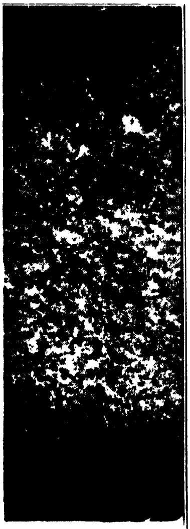
## Steel of Various Makes, Different Sections, Treated ABNORMALLY.

Work continued to too Low Temperature.

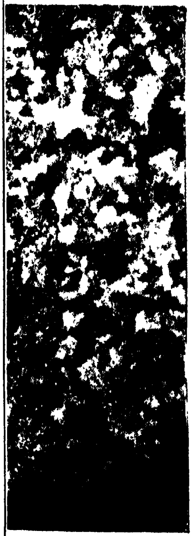


53

54



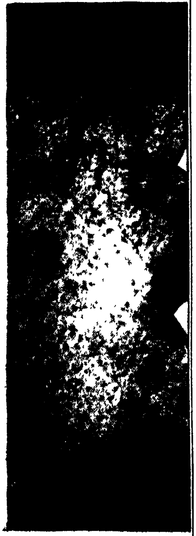
55



56

57

58

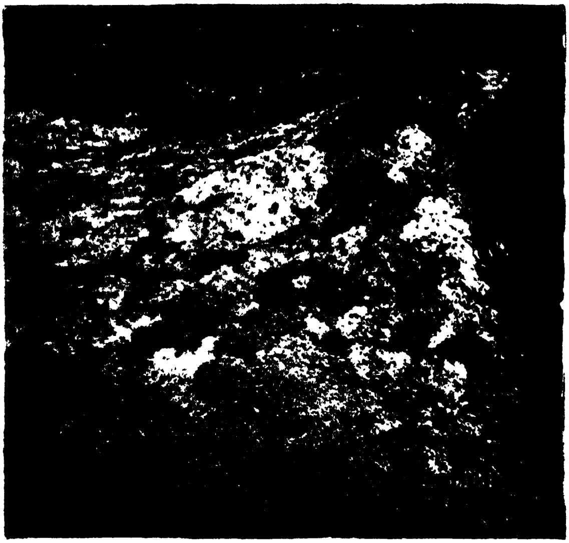


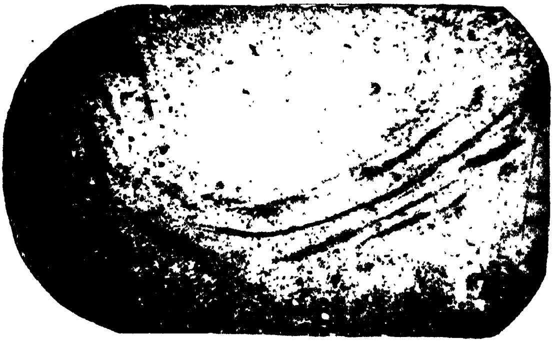
59

PLATE XI.

## Steel of Various Makes, Different Sections, Treated ABNORMALLY.

Work continued to too Low Temperature.


60


61

62

63

64

65

66

67

68

69

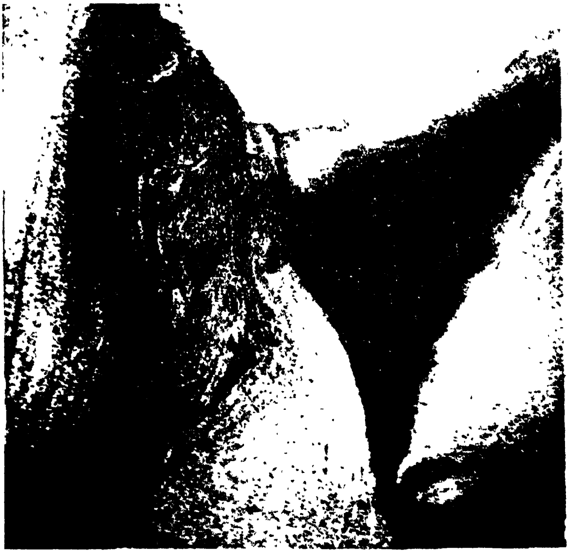
70

71

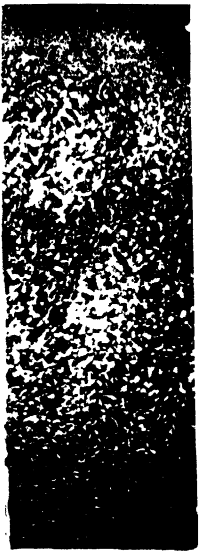
PLATE XII.

## Steel on which Work has been put at too Low a Temperature.

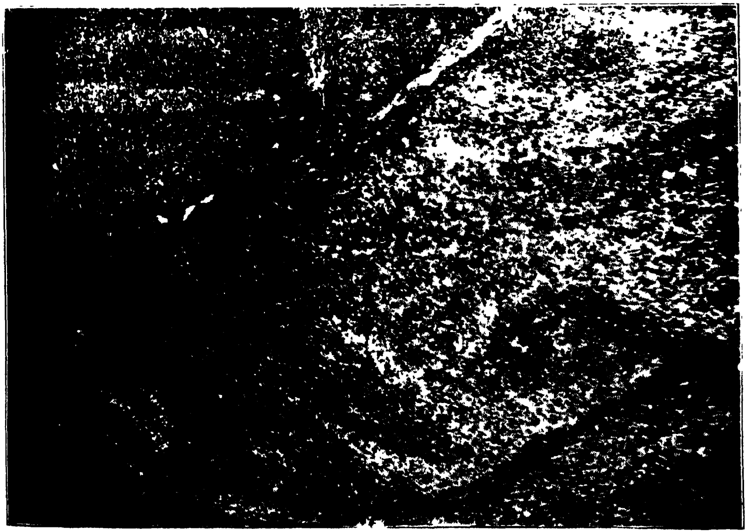
### Hammered Cold (at Normal Atmospheric Temperatures).



73



72



74

PLATE XIII.

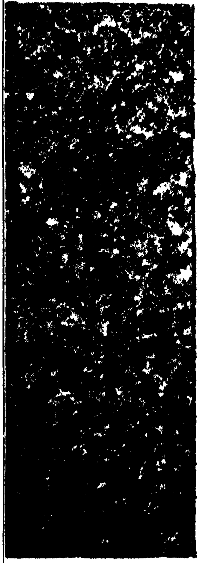
Various Steels of Abnormal Treatment or Composition.

75

76

77

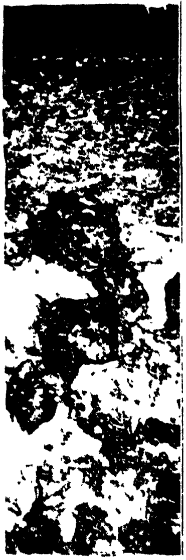
78



79

80

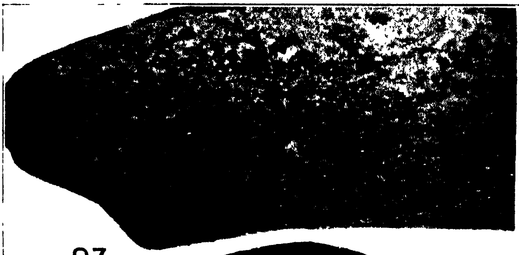
81

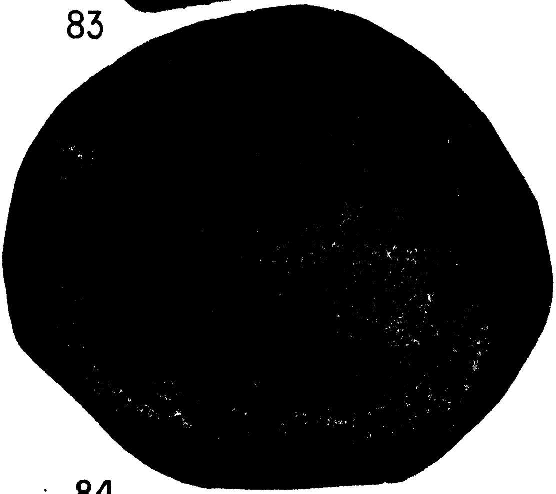


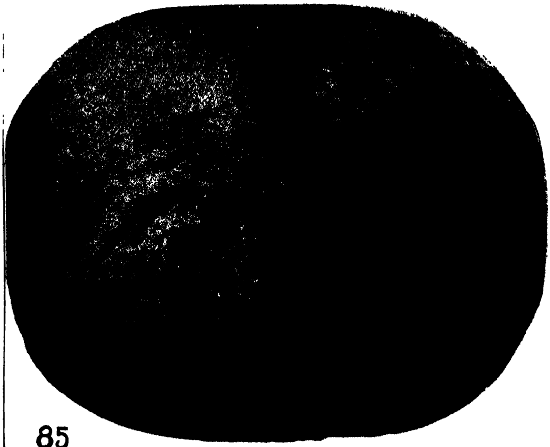
82

PLATE XIV.

## Various Steels of Known and Unknown Treatment.


83


84


85

86

87

*Vertical Illumination.*

PLATE XI.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 Special | V. | 60 | Prepared from Fig. 33 | ·12 | nil | ·02 | ·02 | ·12 | Steam hammered | Corner of same piece as Fig. 59 was taken from, showing flow lines. |
| | | 61 | | | | | | | ,, | Half-section cut from a forged bar showing a cross very plainly. |
| | | 62 | | | | | | | ,, | The half-section about natural size is shown, Fig. 68. |
| | | 63 | | | | | | | ,, | Variously shaped crosses as they appear to the eye in sections, about natural size. All the pieces were forged down to about red heat, and have afterwards been hammered at a blue heat, 63 and 67 under the steam hammer, and 62, 64, 65, 66, with a hand hammer. |
| | | 64 | | | | | | | ,, | |
| | | 65 | | | | | | | ,, | |
| | | 66 | | | | | | | ,, | |
| | | 69 | ,, ,, ,, 25 | ·135 | ·055 | ·044 | ·06 | ·35 | ,, | Appearance to the eye of section of bar forged *cold* under the steam hammer from $\frac{3}{4}''$ square to $\frac{1}{2}''$ square. The peculiar shaped dark part in the centre was quite clear to the eye before etching, being brighter than the rest. In grinding it behaved as if decidedly harder than the rest. Fig. is about natural size.<br>Parts of the same, magnified more, are shown Figs. 72, 73, and 74, Plate XII. |
| | | 70<br>71 | | | | | | | | Appearance to the eye of sections of plate sheared cold, showing flow lines rendered more distinct by shearing. About natural size. |

## STEELS ON WHICH WORK HAD BEEN PUT AT TOO LOW A TEMPERATURE.

| Paper of May 1898. | | Present Paper. | | | | |
|---|---|---|---|---|---|---|
| Fig. No. | Plate No. | Consecutive No. Fig | | | | |
| | | | PLATE XII. | | | |
| | | | HAMMERED COLD WITH STEAM HAMMER. | | | |
| | | | *All by Vertical Illumination.* | | | |
| ... | ... | 72 | Prepared from Fig. 25. Edge. | ×49 dia. | Note grains smaller at extreme edge and increasing slowly and *gradually* further in, but not very marked layer. Compare with Fig. 47 and other blue heat hammered samples. | |
| ... | ... | 73 | ,, ,, ,, Centre. | ×13 dia. | This shows well the confluence of the flow from opposite sides, resulting in actual parting of the material, such as has also taken place in Fig. 52. | |
| ... | ... | 74 | ,, ,, ,, Near centre. | ×49 dia. | The small hooked part which will be recognised in Fig. 73 magnified more, viz., to same magnification as Fig. 52. | |
| | | | On the whole, the greater penetration to the centre, as compared with blue heat hammered samples, will be noticed. | | | |
| | | | PLATE XIII. | | | |
| | | | STEELS FORMERLY HEATED TOO LONG AT NORMAL TEMPERATURE, REHEATED RAPIDLY, AND WORKED IN VARIOUS WAYS. | | | |
| | | | *All by Oblique Illumination* × 49 *dia.* | | | |
| 26*b* | IV. | 75 | Work *above* critical temperature . . | This is Fig. 6 rapidly reheated and structure thus broken up, then | forged at yellow heat and *chilled* in water at cherry red. Edge . | Note, reheating has broken up grain, as seen in centre, but in outer portions large grains have again formed, being again broken up at extreme edge, probably through chilling. This shows clearly why, though prepared from Fig. 6, it was not extremely brittle. |
| 26*b* | ,, | 79 | Work *above* critical temperature . . | | forged at yellow heat and *chilled* in water at cherry red. Centre . | |
| 26*a* | ,, | 76 | Work *above* critical temperature . . | | forged at yellow heat and *cooled slowly.* Edge . . . . | The same action has taken place here, but probably owing to absence of chilling the large grain extends right to the edge. |
| 27*b* | ,, | 77 | Work *below* critical temperature . . | | forged to low red and *chilled* in water. Edge . . . . | These show the breaking up of grain due to rapid reheating, and no fresh growth has taken place owing to work at lower temperature. See Fig. 85 for cross due to forging seen in Fig. 78. |
| 27*a* | ,, | 78 | Work *below* critical temperature . . | | forged to low red and *cooled slowly.* Edge . . . . . | |
| 27*c* | ,, | 80 | Work *below* critical temperature . . | | forged to blue heat and *chilled* in water. Edge . . . . | Worked to a still lower temperature, and chilling, have given a finer grain, which from the brittleness shown by the mechanical test, was evidently in a strained condition. |

### *Other Samples.*

| | | | | |
|---|---|---|---|---|
| ... | ... | 81 | Normally treated steel of *abnormal* composition, viz. phosphorus ·16 per cent. Edge. 2" sq. section . . . . . | Note size of grain as compared with Figs. 1 to 4, Very slightly larger, certainly not likely to be confounded with samples which have been heated for too long time, as Fig. 6. |
| 43 | VI. | 82 | Piece of acid open-hearth steel plate heated three hours in ingot furnace. Edge. Etched deeply with 10 per cent. nitric acid | Note outer carbonless band, and large grains just beneath this. |

## PLATE XIV.

### VARIOUS STEELS OF KNOWN AND UNKNOWN TREATMENT.

| | | | | |
|---|---|---|---|---|
| 43 | ,, | 83 | Same as Fig. 82, Plate XI., but magnified 7 dia. Oblique illumination. | The prolonged heating has caused growth of grain right through the piece. |
| 40 | ,, | 84 | ,, Fig. 23, Plate III., ,, 7 dia. ,, ,, | An example of the carbonless ring at low magnification. Many of the rings end much more abruptly than in this case. |
| 27*a* | IV. | 85 | ,, Fig. 78, Plate XI., ,, 7 dia. Vertical ,, | Note the curved cross due to forging at low red. This is only one example of many more or less perfectly observed crosses seen in various sections. It will be noticed in this case, the material being comparatively soft, the arms of the cross are curved. |
| ... | ... | 86 | Sample of ¼" wire rod, magnified 49 dia., oblique illumination. It was desired to ascertain whether this had been subjected to any excessive or abnormal heat treatment. It contained carbon ·04 per cent., silicon nil, phosphorus ·055, manganese ·26. The photograph shows clearly from the normal size of grain, its regularity, and the absence of a carbonless band or large grains at the edge, that it has received perfectly normal treatment. Compare Fig. 17, Plate V., ⅜ rod, which has proportionately larger grain. | |
| 4*a* and 4*e* | I. | 87 | Sample of brittle or "rotten" wire rod, about ½" dia., magnified 49 dia., oblique illumination. This contained carbon ·05 per cent., silicon trace, sulphur ·041 per cent., phosphorus ·06 per cent., manganese ·041 per cent. Its brittleness (as shown by fracture in paper of May 1898) was clearly due to excessive or prolonged heating, and probably finishing at too high temperature.<br>Note the very large grains which, instead of being similar to those in Fig. 17, Plate V., as would have been the case had it been properly treated, resemble those of Fig. 6, Plate III., though, being of smaller section, they are not quite so large. | |

---

Any one *not* specially trained in microscopy can see clearly from these two Figs. (86 and 87) to which class of steel they belong, and the nature of the treatment they have received.

## *DISCUSSION.*

The PRESIDENT said, as regarded this paper, so far as he remembered, it was in 1882, during the meeting of the Institute at Vienna, that Professor Bauerman said to him incidentally after the discussion of a paper, "I cannot imagine a more fruitful field of investigation on the part of a young man than that of the microscopic examination of iron and steel." In this matter, as in so many others, Professor Bauerman had been a prophet, and in the paper just read they had at least one illustration of the excellent work which a young man might do by investigations of this kind. He would only occupy a very few moments, because he wanted to hear the paper discussed by others, not by himself. The microscopic examination of steel was a subject to which during the last four years he had given a great deal of attention —indeed, more than sufficient attention to convince him of what vast importance the subject really was. He ventured to criticise the method the author adopted, or rather to ask him whether he was satisfied that the method of preparation he adopted for the specimens was really the best? For instance, the author used a 10 per cent. solution of nitric acid for deep etching. So far as his (the President's) experience went, nitric acid was a very dangerous reagent to etch with. He had himself used 1 or 2 per cent., and in that view he was supported by the high authority of Osmond, who considered that nitric acid should be used very sparingly and with great caution, as the interpretation of the results required much experience. Both Osmond and himself by far preferred to polish in relief on some comparatively soft substance, such as wood covered with parchment, and then to etch, or rather to stain, the various constituents by a strong aqueous solution of liquorice. That was the method which, so far as his experience went, gave infinitely the better results. Then again he would ask the author whether he did not consider his magnification somewhat low? He considered that a magnification of 100 diameters was preferable, as affording a useful method of classification; but he was by no means sure that his judgment was correct on this point; but it must be borne in mind that even if the method the author adopted might not ultimately prove to be quite the best that could have been used, that in no way lessened the value of his classification and generalisations, which were excellent. Again he would ask whether it would not be better to adopt some regular method of measuring the temperatures? Having an excellent and simple method of measuring temperature at hand, they surely ought not to speak of a "blue heat" or a "white heat," but should simply insert a little thermo-couple, and ascertain at what temperatures they were working, especially in all matters upon which classification was based. As regarded taking the sample, that again was a most important question. It did not do, as the author had so well said, to cut off a corner, and think that that would represent the mass. If, for instance, they were taking photographs of a steel rail, it was better to take a section of the entire rail—a transverse section—and etch the whole of that section with strong sulphuric acid, and then from such an entire section they could see the point which was best worthy of examination. No doubt what applied to a rail would equally apply to any other mass of considerable size under examination. He had not intended to speak at such length, because, as he had said, it was the opinion of others he wanted to elicit. He would now ask Mr. Greiner, who had made valuable communications to Institutes on the Continent, and had given much attention to the subject, if he would open the discussion.

Mr. A. Greiner, Member of Council, said that this question of microscopic research had been followed up at the Cockerill Works in Seraing for four years. They had a very good microscope, and they also had a very good man who used the microscope in these researches. Of course in four years he had obtained a great deal of experience in the use of the microscope; nevertheless, they had up to now not reached a result which was sufficiently satisfactory to them. There was a very great difficulty in the matter. Mr. Ridsdale was quite right in limiting his researches to one class of steel, and leaving the examination of medium steel and hard steel for other researches. The field open before him, when he examined the soft steels, was large enough, and it was the most practical. What was a soft steel? A soft steel was just the steel they had in their ordinary practice. According to the analyses given in the tables at the end of the paper, there was a great variation between the different elements constituting the steels, but practically they were about the same steels. Whether the steel contained 0·1 or 0·15 of carbon, or 0·02 or 0·03 of silicon, did not make a great difference. The sulphur and phosphorus shown were also very well within the limits found in ordinary practice. He therefore thought that the experiments made by Mr. Ridsdale gave a very good average, taken altogether. But there was a very great practical difficulty in getting satisfactory results from these microscopical examinations. It would be well, first, if they knew the rules for preparing the samples. It ought, if possible, to be recognised that all samples should be of a certain size and prepared in a certain way. If that were not done, they would be working in the dark, and investigators would get results which would not be comparable. Secondly, he thought it was also necessary that they should have a standard of magnification, instead of one investigator magnifying to 100 diameters and another going up to 400. Then, again, the photographs taken by one man were very different from those taken by another; and yet they were dealing with just the same steel. This added to the great darkness in which they were placed. He remembered the time when they had to make analysis of carbon after the method of Eggertz, the well-known Swedish chemist. At first, for months—he would not say for years—they could do practically nothing with it; one found 0·3 per cent. of carbon, another 0·4, and another perhaps 0·5. That was because they had not a good standard. They wrote to Eggertz, and asked him to send standards. He sent them pipes with coloured liquids in them, and then the same colorimetric test was adopted at all the works in Belgium. They could now be sure that the colorimetric tests were very well made. Why could they not, similarly, have a standard for such very difficult things as microscopical researches? He should like to see—and he hoped it would come in time—the production of a little box containing ten or twelve or fifteen samples of soft steel, one taken from a hammered ingot to a given size, another taken from a bloom or a billet of same, and each having this and the other particular qualities — that is, having been heated normally, or having been cooled under certain conditions. and so on. The box should also contain samples of steel from a tin plate or wire, for example. Such a box, perhaps costing £2 or £4, would be a very great help in practice; and he thought that without such a box microscopical researches in works, whose great importance he fully recognised, would not progress as much as they ought to do.

Mr. F. W. Harbord congratulated the author upon taking up the subject of the heat treatment of steel, which he believed was one particular branch of research which the microscope could especially assist them in. His experience with the microscope was, broadly, that the special point on which it did give information was the particular heat treatment to which the steel had been subjected; and it was in this direction that they might reasonably expect more assistance than in any other. It was, of course, not necessary to go to the microscope for the actual chemical composition, because that could be obtained by the usual analytical methods. In the ordinary course of his work he was constantly examining axles, and usually he could tell by the microscope whether an axle had been tempered in oil, whether it had been annealed, and so on. He found he could get at those results with a magnification of about 100 to 140. Of course it might be that in very soft steels Mr. Ridsdale preferred a lower magnification; that was a matter which each man must decide for himself. He believed that this question of the heat treatment of steel was one of the greatest possible importance, and he hoped it would be followed up by other practical men.

Mr. J. E. Stead, Member of Council, said that microscopists had a great deal to answer for in not doing what practical men thought was necessary for the sake of lucidity. It was extremely difficult to bring to the minds of those who did not possess a microscope, and had not got the facilities for examining the pieces of metal themselves, what microscopists really saw. A full and proper illustration of any piece of steel was an exceedingly complex thing. Take any one of those specimens that Mr. Ridsdale had brought before them that day. In order to give them a proper idea of its structure, the microscopist would have to commence by giving them a very low magnification view, then a still higher magnification, and so on until they got to a photograph of, say, a thousand diameters. The Iron and Steel Institute, and every Institute, were very chary about publishing more photographs than a certain number. Mr. Ridsdale had got about eighty-four photographs. If he had to bring to their minds all that he saw, he would want a much larger number. Examining steel was very much like examining a country. From a balloon they got a general idea of a country. They saw patches of city here and forest there; they had a bird's-eye view, in fact. When they came lower and lower down, they began to find the patches resolve themselves into individuals; and eventually, when they got near enough, they might see the individual bricks of which the houses were built and the leaves on the trees. If they placed the eye close to the leaf of a tree or the brick of a building, they would only see that leaf or brick, and from that point would only see a very small detail of what they saw at a greater distance. If they wanted to have an idea of the whole of a country, they must commence looking at it from a great distance, and go nearer and nearer, until eventually they got the whole into their mind. It was just that way in studying steel. His advice to members was to get the steels and examine them for themselves, for in ten minutes, or even in one minute, with their eye applied to the microscope they would learn a great deal more than it would take ten or twenty hours by either drawings or photographs for the microscopists to reproduce what was seen. He would suggest to Mr. Ridsdale that, as he had already given them a lot of valuable information, he should be prepared to give members who wished to study this matter sections of the steels, so that they could polish them up and examine them for themselves. He perfectly agreed with Mr. Ridsdale's statement that they saw a great deal in the structure which gave them the history, or some of the history, of the heat or other treatment to which the steel had been subjected after it was cast. He objected to Mr. Ridsdale trying to separate what he called the scientific from the practical. Even in Mr. Ridsdale's own work he had to go through a regular systematic series of purely scientific investigations before he could arrive at a practical conclusion. The purely scientific many of them were working at, and they hoped it would lead them into practical results in the end; but if they wanted practical results straight off, and without a good deal of pure scientific study, the chances were that they would be very much disappointed. Mr. Ridsdale had shown that the size of the grain had some relation to the diameter of the section. That, he thought, had not been brought before them before this meeting. If they took an ingot and rolled it down to an inch in size, and then rolled it down to a smaller size, they would find that the size of the grain of the finished product was in proportion to the diameter of the piece rolled. They knew that that was more or less so in high carbon steels, but in the softer steels they had not had it previously proved. There was another point with reference to what Mr. Ridsdale described as the separation of fibre in rolling. That was very interesting, and he had no doubt at all that it accounted in a great measure for the production of those blisters in tin plates which were so very objectionable. The fibre, or rather, to use a better term, the plates of which steel and iron were built, when the metal was being rolled cold or at a dull red heat, slipped over each other and arranged themselves in parallel layers. The metal was more easily broken or split along or between these plates than in other directions, and if there was a honeycomb or weak place, that would increase the weakness. When the material was pickled in acid, it would appear from some cause gas was evolved in the centre of the sheets, and in consequence of the feeble cohesion between the crystalline plates the steel was split up and the gas generated formed a blister. The star structure Mr. Ridsdale had referred to in his paper and shown in the photographs was instructive. He had himself shown some very similar sections a year and a half ago at the meeting in London, and since that time he had very thoroughly investigated them. The study had led him to the conclusion, and proved almost conclusively, that when they cold-hammered a square bar of steel first on one side and then on the other, a star structure was developed, the point of the star terminating at the corners, and that in the portions of steel constituting the stars the crystalline plates were arranged parallel or nearly so, leading to the conclusion that the steel flowed most freely along the portions between the corners through the star section.

The PRESIDENT invited a new member of the Institute, Professor B. Porter, Professor of Metallurgy at the University of Montreal, to continue the discussion. He did not know whether that gentleman had given the matter much attention, but he did know that he presided over a most magnificent series of laboratories, which were the envy of every one from this side who visited the great University of which he was a Professor.

Professor PORTER felt he had no right to speak after the other gentlemen who had taken part in the discussion, because, while every one who had thus far spoken had done something in this very important field of work, what he had done was so very little that he would not have mentioned it at all. As the President, however, had so kindly referred to the University which he represented, he might say that, whilst very good work had been done, as they all knew, here on the Continent and in the United States, in the study of microstructure, so far as he knew, little or nothing had been done by his country, Canada. But he was able to say that, thanks to the very handsome provision made by one of their public-spirited Canadians, he had now the means for commencing some researches which he hoped would be worthy of taking a place in the series that had already been so long under way in the Iron and Steel Institute. He was now engaged in equipping what he hoped would be as good a laboratory for micro-investigation as any existing. He had recently received provision for endowing at least one skilled man in this work, and he hoped that, although late, Canada would soon take a part, at least, in this exceedingly important matter.

The PRESIDENT said he entirely agreed, as they all must, with the importance of the remarks made by Mr. Greiner, who insisted on the necessity for standards for micrographic examination. That had been found to be the case, and he was anxious to say from the chair how important he considered it to be, and that he intended to take steps, with the permission of the Council, to bring some arrangement for the preparation of standards into effect. And with regard to the action of nitric acid, he found, on reference to the paper, that the author referred, under the sub-head "System of Examination," to nitric acid of varying strengths, 10 per cent. and 20 per cent.; but it was carefully defined as being for "deeper etching." Although he still thought that the author's method was not quite the best that might be adopted, and infinitely preferred polishing in relief and staining with liquorice, still he wished to point out that in commenting on the use of nitric acid he had in his mind a phrase he had once used to him: it was, "Méfiez-vous de l'acide nitrique."

Mr. RIDSDALE, in reply, said he entirely agreed with the President and with what Mr. Osmond said, that nitric acid was rather a dangerous agent to use. He did not, as a matter of fact, use nitric acid very much; but there was a progressive system of examination, which might include nitric acid, if the circumstances warranted it. So far, he had found the particular method selected the best; but it was only one possible method. It was very much the same as in the case of photography. Each man found that he liked his own developer, and that he could get the best results with his own developer. So it might be with the etching medium employed. As regarded the measurement of temperatures, he certainly felt that his inability to give absolute temperatures was a weak point all through the paper; but they would readily see that in practice it was most difficult, if not impossible, to do that. To begin with, when a sample of steel came in for examination, there was no record of the temperature stated in exact terms. Then, even supposing they could define 750° to 900°, say, as a suitable temperature to finish steel at, until they arrived at the point where every furnace had a pyrometer attached to it, he did not see that they would get very much farther forward. If he took a number of pieces of steel to the works of any friends who were kind enough to offer him the use of their furnaces, and he wished to put pyrometers in and to keep the whole work of the place back whilst he took measurements, he knew that there would be a great deal of friction with the men. He thought that was a work that should be done at some Engineering College, where they had the time and the appliances, and where manufacturing considerations were secondary. In regard to Mr. Greiner's observations, they had decidedly found their system of examination of practical use. They had been able, in several instances, to satisfy customers wanting information as to the treatment steel had undergone; and had found it useful in many other ways. That was a thing that would develop more and more. As he had already said, he had only touched the fringe of the subject. Mr. Greiner had very aptly drawn an analogy between the necessity for standards in this case and in the case of the Eggertz colour carbon method. They all knew that unless the conditions under which the standards were dealt with were identical, they would not get reliable results. As regarded the box of sections or samples, he would remind the meeting that most of the photographs he had shown only covered, say, from $\frac{1}{32}$ to $\frac{1}{16}$ of a square inch, so that he did not think the samples in themselves would be very much use. Again, he had, so far, found it impossible to preserve sections properly polished and etched for very long together in perfect condition. There was a method of covering them, but despite that, rust crept in after a few months. He had some of the pieces of rod from which the samples mentioned in the paper were taken, from which he should be very pleased later on to saw sections, and to supply them as far as possible to any one desirous of them. As regarded the question of standards, he thought that in practice photographs would have to be relied upon. He was preparing books full of standard photographs, so as to be able to turn up at any moment the photographs for any particular class of steel, and compare them with the unknown sample. As he had said before, they had not simply to satisfy themselves; they had to satisfy other people. They could not carry a microscope about with them, and get any one they were talking to to look through it, and follow exactly what they wished him to see. But they could get distinctive photographs. Referring to Plate V., they would find that No. I. was a normal steel, and that No. VI. was the same steel re-heated to the normal temperature, but for too long a time. There could be no confusion as to those two; any one could see in a moment that the treatment had been very different. They were both off the same billet, but had been treated in different ways. Mr. Stead was quite right about the thousand photographs being necessary; he had got many hundreds at present, and was adding to them. He was sorry that Mr. Stead still thought that he wished to separate the scientific from the practical. But he would point out that to many of the members the chief use of science was for practical ends; if they could not prove that what they were doing was going to mean so much £ s. d., their work probably would not be altogether appreciated. He fully agreed that a great deal of purely scientific work must be done before they could get practical results. As to the size of the grains, on which Mr. Stead had laid special emphasis, figures 1 and 17 on Plate V. showed two samples of different size of grain in two sections of normal steel—No. 17 being from a rod $\frac{3}{8}$ inch in diameter, and No. 1 from a 2-inch billet. They could see how much larger the grain was in the billet than in the rod. As regarded the production of blisters, Mr. Campbell, in his paper, referred to porosities in the steel; and that was the sort of thing he alluded to when he mentioned the development of these blisters in sound steel. He did not know that he could say any more, but if any further points cropped up, he would reply to them in correspondence.

## *CORRESPONDENCE.*

Mr. H. Le Chatelier wrote that he had read Mr. Ridsdale's important paper with very great interest. The method there described of applying micrographic analysis to a series of test-pieces, of which the previous treatment was known, would render available to manufacturers a means of investigation that had previously been rather of scientific interest. To render micrographic analysis entirely practical, however, there was much need for improvement in the two essential operations on which so much depended, namely, the polishing and etching. As far as speed was concerned, very satisfactory results had been obtained in the production of the polished specimens. They were cut with a thin emery disc about 3 millimetres in thickness and 300 millimetres in diameter, running at 2000 revolutions. With the expenditure of 2½ horse-power a bar of iron 1 centimetre square, in cross section, could be cut through in a minute. Even hardened steel could be cut in this way, but naturally more time was required. Rough grinding and polishing for speedy accomplishment had also to be done by machinery. One of the best types that had been invented and put to practical use was the treadle machine made by Messrs. Grauer, 46 Myddleton Street, London. The revolving axis was mounted horizontally in ball bearings. For laboratory purposes, the felt wheels usually employed for polishing purposes were replaced by wooden discs, of which three had emery cloth of different degrees of fineness glued on both sides, six in all, and the fourth wheel had cloth on both sides. The emery-coated discs were used for grinding, and the polishing was performed with calcined alumina, prepared by igniting ammonium alum. The powder was mixed into a stiff paste with suitable proportions of paraffin or stearine, and applied at intervals to the cloth-covered wheel. Calcined alumina had the advantage that it acted more energetically than rouge. The polishing was not very perfect perhaps, but it was done much more rapidly, and was quite good enough for current work. The operations of grinding and polishing a sample of steel took about two minutes.

It was in the method of etching to develop the structure of the grain, however, that so much room was left for improvement. The quick methods now adopted had the disadvantage of causing irregular pitting on the surface. Often it was very difficult to distinguish the features appertaining to the boundaries of the grains, the composition of the grains, and accidental irregularities due to etching. Two distinct methods of etching were wanted—one to show only the joints between the grains, like ammonia did in the case of copper, and the other to differentiate the slight irregularities in the individual nature of the separate grains.

Mr. Ridsdale, replying, wrote that, with reference to Mr. Le Chatelier's remarks, he had not seen the copper disc described by

Mr. Le Chatelier, but from the description could not see what advantage it offered. With an ordinary hand hack-saw, a bar of iron or steel from soft up to 0·5 per cent. of carbon and one centimetre square could be cut through in one minute or less with an expenditure of one man-power, as against 2½ horse-power described by Mr. Le Chatelier. As regarded grinding and polishing, they used one of Mr. Stead's handy little machines, which could be worked by hand or power. They drove it with a little hot-air engine worked by a Bunsen burner. This machine also had the wooden discs described, covered, some with emery paper and some with cloth. The time taken depended on the size and nature of the sample; some polished up much more quickly than others, but two minutes for the entire operation was a *very* short time, especially as the discs had to be changed several times. As regarded etching, this could only be learned by continued actual experience, and with this satisfactory results could be obtained by various methods. He thanked Mr. Le Chatelier for the interest he had been kind enough to take in his paper.

The PRESIDENT, in proposing that the usual vote of thanks should be given to the author, said that standard specimens must be prepared at standard temperatures. He would assure the author of the paper that there was no such thing as a difference between practical and scientific work. The methods were exactly the same—patient observation and record of experiments; and the scientific work of one generation became the practical work of the next.

The vote was agreed to unanimously, and the following paper was read:—

# PIG IRON FRACTURES AND THEIR VALUE IN FOUNDRY PRACTICE.

BY JAMES WILLIARD MILLER.

IN a paper entitled "The Yard Grading of Pig Iron," read in December 1898 before the Foundrymen's Association of Pittsburg, Dr. William B. Phillips, editor of the *American Manufacturer and Iron World*, and one of the best-known chemists in America, gives a curious account of the present method of grading pig iron. Of course, like many of the good things in the iron and steel world, the method of grading pig iron originated in Great Britain several hundred years ago. Dud Dudley, in his petition to King Charles I. in 1660 on the subject of the manufacture of pig iron,* states that there were then made three kinds of iron, to wit, in the original words: "The first sort is Gray Iron, the second sort is called Motley Iron, of which one part of the Sowes of Piggs is gray, the other part is white intermixt; the third sort is called White Iron; this is almost as white as Bell Mettle, but in the Furnace is least fined, and the most terrestrial." The author goes on to say, "I may take occasion here to speak of the Nature of Coldshare Iron, which is so brittle, if made of the grain Oare or Ironstone, would be almost as brittle as some Regulus Antimonii made Iron, for with one small blow over an Anvil you may break the biggest Bar that is, if it be perfect coldshare Iron—nay, the plough-man often breaks his Share-point off if it be made of coldshare Iron. But perfect tough malliable Iron will not break feasibly in hot-heat or cold, as coldshare will, or red-hot as Sulphurious veneriated redshare Iron will, but yet tough enough when it is cold. All of which aforesaid qualities of Iron the Authour well knoweth how to mend their Natures, by finning or setting the finery lesse transhaw more burrow, which are terms of art, and by altering and pitching the works and plates, the fore-spirit plat, the tuiron, bottome, back and breast or fore-plate, by the altering of which much may be done, if the work be set transhaw and transiring from the blast, the Iron is more coldshare lesse Fined, more to the Master's profit; lesse profitable to him that makes it into manufactorage, and lesse profitable to him that useth it, but the Iron made in a Burrow work becometh more tough and serviceable; yet the nature of all Ironstone is to be considered, both in the Furnace and in the finery, that the Sulphurious Arcenical and Veneriating qualities, which are oftentimes in Ironstone, be made to separate in both the works from the fixed and fixing bodies of Iron, whose fiery quality is such that he will sooner self-calsine than separate from any Sulphurious veneriated quality."

---

* "Mettallum Martis," 1665, reprinted in the *Journal of the Iron and Steel Institute*, 1872, No. II. p. 227.

This is the earliest recorded attempt to grade pig iron on the yard, and passed as the most scientific description that had yet appeared. Since that date we have drawn away from the arsenical veneriating quality of pig iron, and have substituted cold-short for cold-share iron, but in other respects the description might be used to-day. If the spirit of Dud Dudley could make the rounds with a pig-iron breaker and grader, he would feel perfectly at home, and would rejoice that the art which he founded two hundred and forty years ago had not progressed much beyond its original lines.

Dud Dudley was satisfied with three grades of iron, whereas six grades are now universally recognised, which, however, cover the ground but little better than did Dud Dudley's three grades—in fact, not so well. In the youngest district in America, where now about 30 per cent. of all the foundry iron in the United States is made, thirteen distinct grades have been established, still leaving room for more.

The grader, in conscientious sorting of the iron into its different grades, ever and anon runs against a fracture that fits neither grade so far established; hence a temptation to form a new one.

In the beginning of ironmaking in the district referred to, Alabama, before the nature and condition of the ore and fuel became understood and regulated, the furnaces working under unsettled conditions, operated by green hands from the cotton-fields of Alabama, and directed in many cases by inexperienced managers, who would probably set the blast too much "transiring" or not enough "transhaw," produced iron which would not fit into any of the six existing grades. The conscientious grader, to cover the ground, therefore, added four more regular grades to the six existing, viz., No. 1 silvery, No. 2 silvery, No. 1 soft, No. 2 soft, making ten in all, and still the ground was not satisfactorily covered. No. 4 foundry had to fill the gap between grey forge and No. 3 foundry, caused by the decreasing demand for puddled iron, and to cover the ground more thoroughly, the grades of No. 1 X, No. 2 X, and No. 3 X were inserted between the regular numbers, making fourteen grades in all, with which the manufacturer is burdened, by which the consumer is confused, and over which both wrangle, and which never was a true measure of quality, and therefore never can be a satisfactory one.

The fracture of pig iron is a delusion and a snare. There is not one man in ten, whether consumer or producer, that can tell by the fracture a pig of iron suited for car-wheels from one fit for stove-plates. Where is the line of demarcation between succeeding grades? What is the difference between an open No. 3 and a close No. 2, for example? No matter how carefully the grading is done, there must be, by the very nature of things, in every grade some pigs closer than others. There is, therefore, always room for contention, even when both sides are trying to be fair, which is not always the case.

Mr. E. A. Uehling, in a paper read before the Foundrymen's Association at Pittsburg, gives the following experience due to these facts:—

A lot of No. 2 iron was shipped to a consumer. When the date of settlement came, instead of the proper remittance, there came a long letter of complaint stating that the iron was not up to grade; that fully 50 per cent. of it would not go better than No. 3, and that a reduction in price must be made on the iron equal to the difference in the market value between the grade sold and that actually shipped, viz., 50 cents a ton.

The case was worth investigating. When the furnace representative arrived, he found a lot of samples of the iron in the office awaiting his inspection. The iron was from the lot, there was no doubt of that, and the grade was not better than an open No. 3. He knew that straight No. 2 had been shipped. So closer investigation was necessary. He went to the pig iron yard. The attendant furnished by the customer broke a lot more of the half pigs with the same result—an open No. 3 at best. But the furnace representative happened to be equal to the occasion. He helped himself to some of the iron and broke it, and to the pretended great surprise of the purchaser, nearly every pig showed a fracture much nearer No. 1 than No. 2, and the iron was accepted as sold.

As another instance of the loss sustained by the manufacturer of pig iron owing to the present method of grading iron by fracture, I will take sufficient of your time to give you briefly the story of a concern at present doing business in the United States in the manufacture of car-wheels. It is one of the largest in the United States, and its whole business has been based upon, and its wonderful success is owing to, the fact that its competitors insisted on buying pig iron by fracture, and making their mixtures from that basis, whereas the concern I speak of buy their pig iron irrespective of fracture, except as it regulates the price, making up their mixtures for their castings wholly by chemical analysis. Some years ago this concern started with a small capital in the manufacture of car-wheels. The organiser of the company realised the fallacy of depending on fracture as a measure of value, and taking fracture as the basis for the quality of the car-wheels made from it. He went to the manufacturers of foundry iron, and bought what was considered by his competitors, because of fracture, the lower grades of foundry and even forge iron. He bought this class of iron at comparatively low prices, and had it brought to his foundries—of which there are several located at different points—at one of which I personally know he smelts over 100 tons a day. There the chemist begins his work. He analyses each lot, and from the so-called low grade irons calculates the mixtures from which the car-wheels are made, which to-day practically control the trade in the United States. This is only one of the many instances illustrating what chemistry can do in the foundry, and it is rather astonishing that so many foundrymen still go on in the old way, losing sight of their own interests, making trouble for themselves as well as the producers of pig iron, without any compensating benefit, adhering to the method of Dud Dudley, setting the blast "transhaw" and "transiring" to overcome the irregularities born of unreliability of the fracture as a measure of the quality and character of the iron used.

The fact is that nearly every pig of iron varies in grade from one end to the other. Not infrequently you can show up three distinct grades in one and the same pig. The sow, if at all heavy, is invariably from half to a whole grade higher than its pigs. Is the iron in the sow therefore of a better quality? This is hardly reasonable; yet there is a difference in price from 1s. to 3s. The value of an iron, therefore, does not depend upon its fracture, nor is the fracture any guide as to the special purpose for which a certain iron may be best suited. It is only an indication of the condition of the furnace that produced it, and not an altogether trustworthy indication of even that. The principal factor that determines the grain in the fracture of cast iron is the time given it to pass from the liquid to the solid state. No one is better aware of this fact than the foundryman. Of two castings poured from the same ladle, the lighter casting is invariably the closest grained. The degree of hardness resulting in a casting is not determined by the fracture of the pig iron, but entirely by its chemical composition and the rate of cooling. No. 1 iron may be fitted for car-wheels, or it may be suited for stove-plates, or it may be useless for either. How many can tell what it is suited for by the fracture? No. 1 iron may contain anywhere from ½ to 3½ per cent. of silicon, and the other elements, with the exception of carbon, may vary in the same proportion. Experience has taught the practical foundryman that certain brands of iron are best suited for a certain class of work. He ascertains this by trying first one and then the other, and then several brands in combination in varying proportions, until he gets the right thing. When he has it, he sticks to it. Everything goes smoothly for a while, but suddenly something gets wrong. The castings come out hard or lack strength; have too much shrinkage; are full of blowholes, cold shots, and what not. What is the trouble? The same brands, the same grades, the same mixture. No change at all; yet there must be something the matter with the pig iron, and it must be in that last shipment, of course. There was no trouble until it was put on.

It is thoroughly investigated, and sure enough, the lot contains pigs with close edges, others with dense spots, and more with irregular grain. The iron is not up to grade anyhow, and the whole shipment is condemned. If the price of iron tend downward, the producer is in for all, or at least part of the damage. With a stationary market it is a toss-up, and on a rising market the consumer pockets his loss. In reality the chances are at least even that the trouble was not from the iron at all. There are as many chances as there are brands of iron in the mixture that the wrong brand was condemned. Nine times out of ten it will be used up later on and give the best results. Making up mixtures for special purposes, depending solely upon the fracture to guide you, operates on the same principle on which the Irishman got the weight of his hog. He threw a plank across a log, which he selected with great care, balanced the plank very nicely, laid the hog on one end of the plank and piled stones on the other end until it was accurately counter-balanced, and then he guessed at the weight of the stones. The condition of the sand in the pig beds, the rapidity with which the iron fills the beds, the size of the pigs, are all factors which greatly influence the fracture. If two pigs lying side by side in the same bed happen to be of unequal size, the larger invariably will be of a higher grade than the smaller.

If the large pig is No. 1, the small one may not show better than No. 3. Has the quality suffered because the mould was not run full? Yet this pig, with many others whose fracture suffered from similar causes, goes to the No. 3 pile, and brings correspondingly less per ton. The reverse also holds good. By proper coaxing a No. 3 can be elevated to a No. 1, and in order to please the consumer who buys on fracture, the producer does all the coaxing he can by making the pigs large, covering them up with sand, providing a third casting bed, &c., to give all the time possible for the iron to cool. Except in very wide limits, the fracture of pig iron is simply something by which to guess the quality. It is the pile of stones that counterbalance the Irishman's hog. It is something to quarrel about, and the sooner grading by fracture is abandoned the better for all concerned. Chemical composition is the only true guide by which iron can be judged intelligently as to its quality and fitness for the purpose in hand. Chemistry in the foundry is still in its infancy and much is yet to be learned. But with Foundrymen's Associations established all over the country, composed of intelligent and energetic workers for the practical application of scientific principles, the advantages of chemical analysis as well as synthesis are beginning to be more generally understood and appreciated. It is only a matter of time when the benefits will be fully realised.

Another very eminent authority in the United States on cast iron, Dr. R. Moldenke, says at the conclusion of an exhaustive series of tests made under the auspices of the Building Department of New York, that the present method of analysing iron by a chemist in the shape of an Irishman with a sledge has been gradually merged, in the better conducted plants, into plain pig iron, carrying so much silicon, sulphur, phosphorus, manganese, and total carbon.

The greatest drawback to the practical application of chemistry in the foundry is that with cast iron in the sand in the ordinary way it is almost impossible to get shipments of uniform composition. This is due to the fact that the iron as it flows from the furnace is very irregular; and it not infrequently happens that there is a difference of 1½ per cent. in the silicon from the first to the last bed in a cast of iron of practically the same grade.

This difficulty will be entirely overcome when the old method of casting in sand beds, which, like the grading of iron by fracture, has been but little improved upon since Dud Dudley's time, will have been superseded, as it is bound to be, by the more economical and rational method of mechanical handling.

Running the metal from the furnace into a large receptacle of 20 or more tons capacity will ensure a perfect mixture of that amount, which can be analysed and piled or shipped as what it is with certainty. The time required to transport molten metal from furnace to the machine allows the slag to separate more thoroughly, and an appreciable amount of the sulphur also escapes. The iron is not contaminated by a crust of sand or loam. The producer will know what he has to sell, the purchaser will get what he buys, and the consumer will not have to handle and remelt a lot of sand and scruff, which costs extra fuel and is liable to contaminate the product.

The first gentleman I have quoted describes tersely and accurately the conditions that prevailed up till a very late date, and I dare say it prevails to some extent in many plants at the present day. Mr. Uehling illustrates the difficulties continually arising between producer and consumer, but Dr. Moldenke truly describes what, if it is not already the universal practice among foundrymen, must in that struggle—the signs of which are everywhere apparent in the foundry trade in all parts of the world—lead to the grading of pig iron by its "silicon, sulphur, phosphorus, manganese, and total carbon contents." When the blast-furnace owners and managers have come to the conclusion that the evils which they suffer from, and which they are held accountable for by the foundrymen, can be obviated, if not entirely obliterated, by grading iron in the proper way, then grading by fracture will no longer be the basis of quality and price, and the most prolific bone of contention between the producer and consumer of pig iron will be removed.

Another object which can be accomplished when this comes to pass is that the producer of pig iron can avail himself of some one of the mechanical methods which are rapidly coming to the fore, thus proving beyond doubt that their use is mechanically practicable and commercially profitable to the pig-iron maker in the handling of his product. He will be benefited by a lower cost in the manufacture of his product and by an increased value of the product itself. It is admitted by every man who knows the facts that if iron can be handled from the furnace to the stock pile by mechanical means without having to be cast in sand, you have got a product which is worth more money than if cast in the usual way. Furthermore the foundryman himself will be benefited to an extent that he is at present perhaps not conscious of. I am not prepared to give the exact facts regarding some experiments which have been made in the United States lately in the use of sandless iron in foundry-work, but I am informed from reliable sources that these experiments show a decrease in fuel cost, and a distinct saving in bad and imperfect castings, and that more iron can be melted in a given time.

I am not here to-day to advocate the adoption of any particular method of mechanical casting; that is a matter which each man will decide for himself, taking into consideration the output of his furnaces, the condition under which his product must be handled, and the wishes of his customers. It is only necessary for me to state that in the United States large concerns engaged in the manufacture of agricultural machinery buy sandless iron solely on chemical analysis and not by fracture; and in conversation with the managers of those concerns, they have informed me that they know for a fact that the chemical analysis of the material which they put into castings of their machinery helps them to gauge the cost, and gives them a basis from which to calculate the strength necessary for different parts much better and more economically than when they bought their iron and melted it, depending on fracture.

Furthermore, iron cast by mechanical means has to-day among people who have used it a preference over that cast in sand, and a particular establishment I have in mind in making the above assertion is one of the best-known foundries in the United States, at which they have used sandless iron exclusively for a period of over eighteen months, and the assertions made above are derived from the foreman of the foundry department after a careful tabulation of results obtained.

This paper is not to be considered from a scientific standpoint, but as bringing before the members of the Iron and Steel Institute one of the questions that to-day is demanding attention, and which sooner or later must be solved, both by the producer and consumer of pig iron. The scientific and practical features are so interwoven that it is impossible to deal with it in its present status from a purely scientific standpoint, and my only object has been to bring the general features of the question before the members of this Institute, and to excite such discussion as will form a basis for the ultimate solution of the problem in an amicable manner and in a way that will be beneficial to all parties concerned.

After a cordial vote of thanks to the author, the following paper was read:—

# THE PRESENT POSITION OF THE SOLUTION THEORY OF CARBURISED IRON.

BY ALFRED STANSFIELD, D.Sc., Assoc.R.S.M.

## INTRODUCTION.

IN view of the large amount of attention that has recently been devoted to the constitution of steel and other forms of carburised iron, and of the importance of the solution theory in explaining the mutual relations of carbon and iron, it appeared desirable that an attempt should be made to embody in an accessible form the main features of this theory. It is usually admitted that metallic alloys behave as saline solutions do, and bringing carburised iron into line with alloys is rendering a good service to industrial and theoretical chemistry. I need not remind members of this Institute that a solution need not be a liquid, but that in certain solids, especially when they are at a high temperature, an added element tends to diffuse itself uniformly through the mass, from which, however, as from the liquid solution, it may be crystallised out on cooling.

Such a solution is white hot steel. It has, in fact, been abundantly proved that a solution need not necessarily be fluid. A mass may be solid and yet retain many of the characteristics of a solution. It has, for instance, been shown * that molecular changes have precisely the same effect in producing crystallisation from a solid solution that the freezing of an ordinary solution has. Just as a body dissolved in water is separated by solidification or freezing, so a body dissolved in a solid may "fall out" when a molecular change takes place. The molecular changes of iron are, therefore, of the first importance in relation to the solution theory of solidified carburised iron.

The solution theory of carburised iron affirms that this substance is, when fluid, a solution of carbon in iron, and that

---

* Victor Rothmund, *Zeit. Physikal. chem.*, 1897.

under certain conditions the solidified mass also forms a solid solution. It further affirms that these liquid and solid solutions obey the ordinary laws of solution, which have been fully studied in the case of aqueous, saline, and organic solutions. The solution theory can therefore be invoked to explain both the mode of solidification of carburised iron and the molecular changes that take place after solidification. The experimental data which enable the theory to be applied are mainly afforded by the pyrometer and the microscope used in conjunction with chemical analysis, but all the other chemical and physical properties of carburised iron must be studied for the sake of the contributory evidence they afford.

The solution theory of carburised iron can be most readily understood by reference to the "Freezing-point Curves" contained in Sir William Roberts-Austen's Fifth Report to the Alloys Research Committee of the Institution of Mechanical Engineers. A diagram of these curves has been lent by that Institution to illustrate this paper, and is reproduced on the next next page.

The diagram embodies the information gained from a large number of cooling curves of carburised iron, which have been obtained by means of the autographic recording pyrometer. It indicates, for each percentage of carbon, the temperatures at which evolutions of heat would occur in a slowly cooling mass.

## THE SOLIDIFICATION OF CARBURISED IRON.

The freezing temperature of pure iron has not been determined exactly, but we may for the present consider it to be 1600° C.*

Carbon will dissolve in molten iron just in the same way as common salt dissolves in water, and in both cases the freezing-point of the solution is lower than that of the pure solvent.

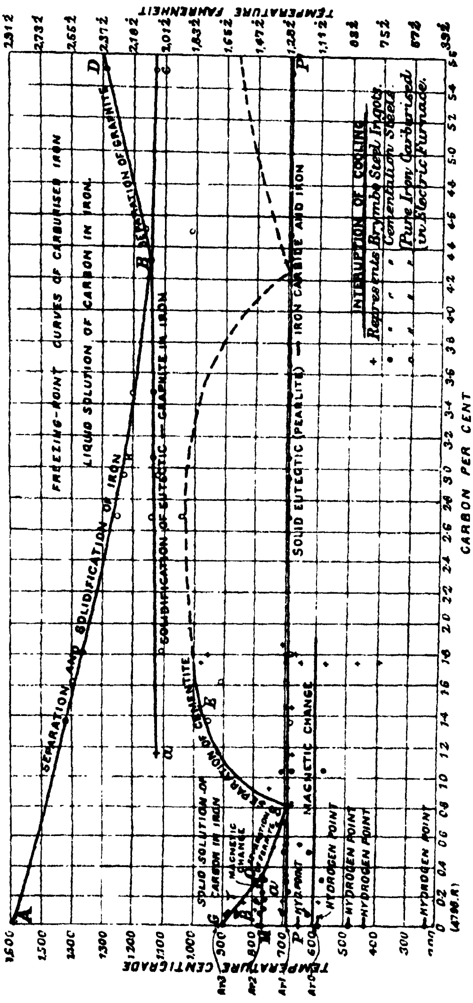
The freezing temperature is continuously lowered with further additions of carbon, as is indicated by the line AB, until at about 4·3 per cent.† the maximum fusibility is attained, and further additions of carbon cause a rise (BD) in the freezing temperature. This is exactly analogous to the behaviour of a salt solution.

---

* Pictet, 1879, *Comptes Rendus*, vol. lxxxviii.

† Percy found that 4·6 per cent. of carbon was the maximum that pure iron could contain without separation of kish.

The first solid to separate from a freezing salt solution is



pure ice if the solution is weak, and pure salt if the solution is strong; similarly pure carbon, in the form of graphite, separates as "kish" from a strong solution of carbon in iron. The first solid to separate from a dilute solution of carbon in iron is either pure iron, or a solid solution of carbon in iron, containing, however, less carbon than the liquid solution from which it solidified.

The residual mother liquor from which either the graphite or the iron is separating becomes correspondingly poorer or richer in carbon until its composition approximates to 4·3 per cent. of carbon. If the solution contains a little more carbon than 4·3 per cent., graphite will separate out, reducing the composition of the residue to below 4·3 per cent. After this some iron will separate out, thus raising the percentage of carbon in the residual liquid, so that, on the whole, the composition remains constant. Thus it will be evident that iron containing 4·3 per cent. of carbon, whether originally prepared of this composition, or resulting naturally as a residual liquid or eutectic during the cooling of a carbon iron solution, must solidify as a mixture of iron and graphite. It will also be evident that the temperature at which it solidifies must be a constant one.

The horizontal line *aBc* shows that in iron containing more than about 1·2 per cent. of carbon there is a residual liquid which solidifies at a constant temperature of about 1130° C. The microscope usually shows the presence of graphite in any alloy in which a point in the cooling curve has been revealed at 1130° C. The very small quantities of graphite indicated in steels having less than about 2 per cent. of carbon may sometimes be converted into carbide during the subsequent cooling from this temperature. The iron, on the other hand, is always subject to changes during the cooling, and these will be considered subsequently.

It has been abundantly proved that eutectic alloys and the so-called cryohydrates (their analogues in saline solutions) are not chemical compounds, as was supposed at one time, but are true solutions when liquid, and are mechanical mixtures of two constituents when solid.

The constitution of the solidified iron must now be considered. Does the iron separate in a pure state, or does it hold some carbon in solid solution? The fact that the eutectic line ABC has not been traced in steels containing less than about 1·2 per cent. of carbon, shows that at 1130° C. iron can hold 1·2 per cent. of carbon in solid solution. It might naturally be inferred from this that at the higher temperatures at which the iron originally solidified it would contain *more* carbon in solid solution. There are, however, certain considerations which do not favour this view. One of these considerations arises from the fact that at rather lower temperatures, such as 1000° C., iron can hold *more* than 1·2 per cent. of carbon in solid solution, so that there is clearly some influence at work which causes, as the temperature rises, a *decrease* in the amount of carbon dissolved by the iron.

Now at 1130° an excess of carbon in iron would tend to separate as graphite, but at 1000° it would separate as the carbide of iron, $Fe_3C$, and this is probably the main cause of the irregularity. It has been suggested [*] that the carbon is dissolved in the iron as carbide at lower temperatures, and as free carbon at higher temperatures, but it is impossible at present to speak definitely as to the nature of the carbon when in solution.

An equation devised by Van't Hoff renders it possible to calculate from the slope of the line AB the number of atoms in each molecule of carbon dissolved in molten iron.

Baron von Jüptner [†] has made this calculation, and finds that the molecule of dissolved carbon contains two atoms in the case of fluid steel, and that in fluid pig iron there are an equal number of two and three atom molecules. The formula of Van't Hoff is, however, only correct for very dilute solutions, and should not be used in the case of pig iron. Heycock and Neville [‡] give a modification of this formula, which is more suitable for such solutions. The author has applied Heycock and Neville's formula, and finds that the molecule of dissolved carbon contains two atoms both in fluid steel and fluid pig iron. [§]

In these calculations the carbon in molten iron is assumed to be uncombined. If the carbon is assumed to exist in solution as $Fe_3C$, very irregular results are obtained, the number of carbon atoms in the molecule varying from 2·6 to 5·8 with increasing concentration. This would appear to be an argument in favour of the simple solution of carbon in molten iron.

---

[*] Baron von Jüptner, *Journal of the Iron and Steel Institute*, 1898, No. I., p. 235.

[†] *Journal of the Iron and Steel Institute*, 1898 and 1899.

[‡] *Journal of the Chemical Society*, 1892, p. 888.

[§] These calculations involve a knowledge of the latent heat of fusion of iron, which has been taken as 20 calories.

All these calculations are dependent on the assumption that the iron separates in a pure state on solidification. If the iron contained dissolved carbon, it would involve the existence of a molecule containing less than two atoms.

As, however, the molecule could never contain less than *one* atom, a limit is put to the amount of carbon which the iron can possibly hold on solidification. If the molecule were monatomic, the iron would contain on solidification approximately one-half the amount which it contained when fluid.

Thus an examination of the lowering of the freezing-point of iron, produced by the addition of carbon, shows that the iron contains after solidification an amount of carbon which is certainly not more than one-half of the amount in the solution from which it separated.

An examination of the amount of heat evolved at 1130° C., by cooling masses containing varying percentages of carbon, strongly supports the view that the iron retains on solidification about one-half the percentage of carbon of the liquid from which it solidified.*

For the present, then, the author wishes to advance the hypothesis that the carbon in fluid iron is monatomic, and that the iron which separates on cooling contains about one-half the percentage of carbon of the liquid from which it crystallised. It will follow on this hypothesis that the eutectic consists of a mixture of graphite, and of iron containing about 2·2 per cent. of carbon.

## FORMATION OF CARBIDE OF IRON.

It has already been mentioned that the carbon which remains in solid solution in the iron probably enters into combination with it when it is cooled below about 1100°, forming the carbide $Fe_3C$. The evidence upon which this rests is as follows.

(1.) The pure carbide of iron, $Fe_3C$, when heated to about 1050° C. or 1100° C., is dissociated, forming graphite and iron containing some dissolved carbon. It might, however, be expected that $Fe_3C$ in solution would be able to exist at still higher temperatures than the free carbide, on account of the osmotic pressure of the released carbon and iron; the extent to which this takes place requires investigation.

---

* The only alternative to this is to suppose that a large amount of combination takes place above 1130° C. between the solidified iron and the still fluid carbon.

(2.) Evidence on this point may also be gained by a consideration of the nature of the constituent austenite, which Mr. Osmond has added to our already long list. This may be obtained by heating a high carbon steel to a temperature above 1050° C. and quenching rapidly in iced brine. The steel is then found to possess a peculiar zigzag structure (when examined under the microscope), and consists of two elements—a hard material resembling martensite, and a softer material, "austenite," which appears to be non-magnetic.

Mr. Osmond has recently shown* that austenite resembles manganese or nickel steels, and, like them, may be rendered magnetic by immersion in liquid air for some minutes. The density of the steel containing austenite is about as great as that of annealed steel, but upon cooling in liquid air it becomes less. The hardness increases at the same time, and approximates to that of martensite.

Mr. Osmond explains that when $\gamma$-iron contains a large amount of (dissolved) carbon (as is the case in high carbon steels above 1050° C.), very rapid quenching enables (part of) the iron to remain in the $\gamma$ form. The subsequent cooling in liquid air enables the $\gamma$-iron to change to the usual form it assumes in quenched steel, that is, partly $\delta$ and partly $\beta$.† Baron von Jüptner ‡ advances the explanation that when high carbon steel is heated to 1050° C., the cementite partly dissociates, producing a solution of free carbon in iron.

## FORMATION OF GRAPHITE.

The formation of graphite from the eutectic of the molten carburised iron, and also at temperatures indicated by the line BD in irons particularly rich in carbon, has been already explained. The mode of formation of the variety of graphite known as "temper-carbon," and the reason for the comparative absence of cementite in rich carburised iron, has yet to be considered. At temperatures between about 1000° C. and 1130° C., the dissolved cementite tends to dissociate, and the carbon may be liberated as "temper-carbon" either directly or after an intermediary stage of simple solution in iron. Conversely, at temperatures below 1000° C., the graphite gradually dissolves in the iron and is converted into cementite, which may fall out of solution on further cooling.

---

* *Comptes Rendus*, 1899.

† F. Osmond, *Transactions of the American Institute of Mining Engineers*, vol. xxvii. p. 876.

‡ *Journal of the Iron and Steel Institute*, 1898.

In high carbon steel the *mechanical pressure* engendered by the separation of graphite (which occupies more space than when in solution) probably limits the formation of graphite during the limited range of temperature in which it can be liberated. In the case of highly carburised pig iron, the large number of flakes of graphite formed on solidification constitute nuclei around which more graphite can separate, and, as the mass is more open, internal pressure cannot well be set up. It is, therefore, difficult to determine the degree of solubility of graphite in solid iron, as it varies so much with the conditions under which the separation takes place.

## THE ALLOTROPIC CHANGES OF IRON AND THEIR INFLUENCE ON THE SOLID SOLUTIONS OF IRON AND CEMENTITE.

Solid iron differs from most other metals, as it can exist in more than one molecular form. The change from liquid iron to solid iron has already been considered, but there remain the changes, almost as profound, from $\gamma$-iron to $\beta$-iron, and from that to $\alpha$-iron.

In pure iron these changes take place on cooling; from $\gamma$ to $\beta$ at about 895° C. (the $Ar_3$ point), and from $\beta$ to $\alpha$ at about 765° C. (the $Ar_2$ point).* The presence of dissolved cementite lowers the temperature at which these changes occur in precisely the same manner as the presence of dissolved carbon in molten iron lowers the temperature of its freezing-point.*

---

* The allotropic varieties of iron are now well known, but it may be mentioned that $\gamma$-iron is non-magnetic, and dissolves carbon and cementite; $\beta$-iron is non-magnetic, but does not dissolve cementite; while $\alpha$-iron is magnetic, and does not dissolve cementite.

To take first steel containing less than 0·34 per cent. of carbon, in which both $Ar_2$ and $Ar_3$ occur; separation of $\beta$-iron commences at a temperature denoted (for each percentage of carbon) by the line GO. Iron in the $\gamma$ form will dissolve about 1 per cent. of carbon (as cementite) at 850°, but $\beta$-iron will dissolve scarcely any, so that the separated $\beta$-iron, being practically free from carbon, undergoes the change to $\alpha$-iron at the normal temperature of 765° C. Meanwhile, as the iron falls out, the residual solution of cementite in $\gamma$-iron becomes richer in cementite, until at 690° C. it is saturated, forming a eutectic solid solution, and the cementite and the iron (in the $\alpha$ form) separate out side by side to form the well-known pearlite. The evolution of heat at 690° C. which marks this change is known as the $Ar_1$ point. The molecular mechanism producing the lowering of the allotropic change point, $Ar_3$, is analogous to that producing the lowering of the freezing-point of iron, and the formulæ of Van't Hoff and of Heycock and Neville are equally applicable to both cases. In calculating the molecular weight of the dissolved carbide from the lowering of the $Ar_3$ point, the temperature and latent heat of fusion of pure iron must be replaced by the temperature and by the heat rendered latent when pure electro-iron changes from $\beta$ to $\gamma$ iron at $Ar_3$.

Sir W. Roberts-Austen, in his Presidential Address,† stated, as the result of such a calculation, that the molecule of dissolved carbon consisted of three carbon atoms, which would mean, supposing that the carbon exists in solution as cementite, that it would have the formula $3(Fe_3C)$; and although a later calculation, in which certain corrections were introduced, results in the smaller figure of two carbon atoms in the molecule, $2(Fe_3C)$, the data involved in the calculation are not yet sufficiently exactly determined to enable a very definite statement to be made.*

---

* The author suggested the analogy between freezing-points and points of allotropic change.—*Minutes of Proceedings of the Institution of Civil Engineers*, 1895–96, vol. cxxiii. p. 260.

Mr. Osmond makes a similar statement at the end of the paper already referred to (*Comptes Rendus*, 1899), comparing the lowering of these allotropic changes to the lowering of the freezing-point of a solvent.

† *Journal of the Iron and Steel Institute*, 1899, No. I., p. 17.

If the steel contains 0·34 per cent. of carbon, the $Ar_3$ point occurs at the same temperature as the $Ar_2$ point, and further additions of carbon result in a lowering, to temperatures indicated by the line OS, of what may be described as the combined point $Ar_{2\cdot3}$. In such steels the excess of iron separates directly in the *a* form, and the residual solid solution is decomposed as before at the point $Ar_1$ at 690° C. The theory connecting the lowering of the point $Ar_{2\cdot3}$ with the number of molecules of $Fe_3C$ in unit volume of the solution, is less simple than when the point $Ar_3$ was alone concerned. A calculation may, however, be made on the assumption that the osmotic pressure required to produce the observed lowering is equal to the sum of the pressures which would be required to lower each point, $Ar_2$ and $Ar_3$, separately.

The number (2·7) obtained in this way for the number of carbon atoms in the molecule does not agree at all with the number (2·0) already mentioned. This discrepancy is represented graphically on the diagram by the decided change in direction from the line GO to the line OS, a change which seems too great to be fully accounted for by the influence exerted by the comparatively small change $Ar_2$ upon the direction of the line OS. The evolution of heat at $Ar_2$ is, however, less abrupt, and therefore less easy to measure, than that at $Ar_1$. The specific heat of iron, moreover (which is involved in these measurements), probably varies extremely with the temperature, and more exact measurements of these evolutions of heat, which represent the latent heat of the allotropic changes, may be expected to produce a better agreement between the results.

When the amount of carbon in the steel has reached an amount which is between 0·8 per cent. and 0·9 per cent., the composition is the same as that of the solid eutectic. Under these conditions the solid solution of cementite and of $\gamma$-iron cools down as a whole, until, at the temperature of 690° C., the cementite and ferrite are mutually saturated, and split up into the characteristic pearlitic structure of cementite and $\alpha$-iron.

---

* The amounts of heat rendered latent during the changes of iron from $\alpha$ to $\beta$ and from $\beta$ to $\gamma$ were obtained from cooling curves of electro-iron (like the one published in the fifth report of Sir W. Roberts-Austen to the Alloys Research Committee of the Institution of Mechanical Engineers). The apparent rise of temperature of the iron was measured, and, after making allowance for the probable loss of heat, it was multiplied by the specific heat of the iron. The $Ar_3$ change from $\gamma$ to $\beta$ caused an apparent rise of temperature of 14·3° C. (including the correction), and this represents 2·86 calories. The $Ar_2$ change from $\alpha$ to $\beta$ corresponded to 4·2° C. or 1·0 calories; but the latter figure may possibly be quite inaccurate.

Still further additions of carbon cause the steel on cooling to become saturated with cementite, which begins to separate at temperatures indicated by the line SE. The residual solid solution therefore becomes poorer in cementite, until at 690° C. it has the eutectic composition.

The conclusions which the author has arrived at with respect to the atomic complexity of carbon in iron are these:—

The carbon in molten iron is in a state of simple solution; the molecule of carbon must then contain one or two atoms, and is probably monatomic. The solidified iron is in the $\gamma$ state and contains free carbon in solution. The molecular weight of this carbon has not been discussed, but it is probably the same as that in the molten iron.

The carbon in solid solution combines with iron, on cooling, to form a carbide, which is probably expressed by the formula $2(Fe_3C)$.

When, on further cooling, this carbide falls out of solution as cementite, its formula may become more complicated; the solution theory affords no information on this point; but Sir W. Roberts-Austen stated in his Presidential Address that the nature of the products of its solution in acids led to the conclusion that the molecule may contain six atoms of carbon, and is at least as complex as would be indicated by the formula $6(Fe_3C)$.

There appears to be a belief that the solution theory is in a sense opposed to, and has gone far to supplant, the older allotropic theory, but this paper will, it is hoped, effectually dissipate such an error, as it shows how entirely the solution theory of the relations of carbon and iron involves the allotropic changes with which the distinguished name of Osmond is so inseparably connected.

## *DISCUSSION.*

The President thought that, before inviting discussion, it was not necessary for him to say how entirely in accord he was with the author of this paper; in fact, the work of the tests had been done by them together. He considered it to be a matter of the utmost importance to bring the carbon-iron series into line with that of the ordinary salts. If once that were done there would be clear light, which, as had been pointed out, was at the basis of the whole metallurgy of iron. Therefore he considered that communication of Dr. Stansfield's to be about as important as any that could well be made to the Institute. It might be difficult to read, its full significance might not be understood for months, or even for years; but it did afford a scientific basis on which the theories and practice relating to the metallurgy of iron might be built up.

Mr. G. J. Snelus, Vice-President, said that at the meeting of the Institute in 1870 at Merthyr he read a paper on the condition of carbon and silicon in iron, in which he mentioned a mode of procedure which, he was sorry to say, had never been further developed. It had been out of all possibility for him to carry it on in later years, but he still thought it was a mode of procedure which might help them in settling some vexed questions. He referred to the mechanical separation of iron by first drilling the material into fine powder, then triturating it still finer, and finally attempting the separation of the particles by *very* fine sieving. In that paper he showed that he was able to separate the graphite from pig iron, and to finally obtain practically pure carbon from ordinary pig iron by a simple process of mechanical separation. He had to point out in that paper an error which the late Dr. Percy made in his work and in his teaching. He referred to the paragraph in Dr. Percy's remarkable standard book, which at that time was quite understood to be perfectly correct, to the effect that "you could not separate graphite from the faces of crystalline pig iron even by a penknife." That was a mistake which he corrected at the time, and it was in consequence of following up that mistake that he was led to this mode of research. He thought that if that mode of research was continued, something more might come of it; for while he was able to separate out the graphite by a process of sifting, he was not able to separate out the silicon. On the other hand, he did find that he could increase in the finer portion the percentage of sulphur. Manganese seemed also to lend itself to that mechanical separation. He ventured to think that if that system were further followed up with great care, it might enable them to see whether the pig iron dissolved carbon *per se* as carbon, or whether it dissolved the carbon as a compound of carbon and iron. He hoped that some of their younger friends would take up that line of research in connection with the mode which had been referred to in the paper, and which had been followed so much by their worthy President. He mentioned it because he thought it was a direction in which their studies could be carried on which would confirm parallel processes in other directions.

Mr. R. A. **Hadfield**, Member of Council, drawing attention to Dr. Stansfield's reference to the fact that graphite might sometimes be converted into carbide, said he had had an interesting proof of that, which it might be of service to mention. He had some specimens of American malleable cast iron, in which the carbon existed almost entirely in the graphitic temper form. Strange to say, without actually fusing that product, he had found it possible to change the tempered carbon into hardened carbon. He thought the idea ordinarily held was that change could not be made without passing the material through a fusion process; but this process showed that graphitic temper carbon might be converted backwards and forwards in a very remarkable manner. He thought that rather bore on the fact which Dr. Stansfield referred to. With reference to the footnote relating to the allotropic varieties of iron, while he wished to pay all respect to Dr. Stansfield's very admirable paper, he thought that footnote should be somewhat qualified, out of respect to the carbonists. It read—"The allotropic varieties of iron are now well known." He thought they were theoretically well known, but he did not think there was any absolute proof of the existence of the three separate forms mentioned in the note. He would mention an

## *DISCUSSION.*

The PRESIDENT thought that, before inviting discussion, it was not necessary for him to say how entirely in accord he was with the author of this paper; in fact, the work of the tests had been done by them together. He considered it to be a matter of the utmost importance to bring the carbon-iron series into line with that of the ordinary salts. If once that were done there would be clear light, which, as had been pointed out, was at the basis of the whole metallurgy of iron. Therefore he considered that communication of Dr. Stansfield's to be about as important as any that could well be made to the Institute. It might be difficult to read, its full significance might not be understood for months, or even for years; but it did afford a scientific basis on which the theories and practice relating to the metallurgy of iron might be built up.

Mr. G. J. SNELUS, Vice-President, said that at the meeting of the Institute in 1870 at Merthyr he read a paper on the condition of carbon and silicon in iron, in which he mentioned a mode of procedure which, he was sorry to say, had never been further developed. It had been out of all possibility for him to carry it on in later years, but he still thought it was a mode of procedure which might help them in settling some vexed questions. He referred to the mechanical separation of iron by first drilling the material into fine powder, then triturating it still finer, and finally attempting the separation of the particles by *very* fine sieving. In that paper he showed that he was able to separate the graphite from pig iron, and to finally obtain practically pure carbon from ordinary pig iron by a simple process of mechanical separation. He had to point out in that paper an error which the late Dr. Percy made in his work and in his teaching. He referred to the paragraph in Dr. Percy's remarkable standard book, which at that time was quite understood to be perfectly correct, to the effect that "you could not separate graphite from the faces of crystalline pig iron even by a penknife." That was a mistake which he corrected at the time, and it was in consequence of following up that mistake that he was led to this mode of research. He thought that if that mode of research was continued, something more might come of it; for while he was able to separate out the graphite by a process of sifting, he was not able to separate out the silicon. On the other hand, he did find that he could increase in the finer portion the percentage of sulphur. Manganese seemed also to lend itself to that mechanical separation. He ventured to think that if that system were further followed up with great care, it might enable them to see whether the pig iron dissolved carbon *per se* as carbon, or whether it dissolved the carbon as a compound of carbon and iron. He hoped that some of their younger friends would take up that line of research in connection with the mode which had been referred to in the paper, and which had been followed so much by their worthy President. He mentioned it because he thought it was a direction in which their studies could be carried on which would confirm parallel processes in other directions.

Mr. R. A. Hadfield, Member of Council, drawing attention to Dr. Stansfield's reference to the fact that graphite might sometimes be converted into carbide, said he had had an interesting proof of that, which it might be of service to mention. He had some specimens of American malleable cast iron, in which the carbon existed almost entirely in the graphitic temper form. Strange to say, without actually fusing that product, he had found it possible to change the tempered carbon into hardened carbon. He thought the idea ordinarily held was that change could not be made without passing the material through a fusion process; but this process showed that graphitic temper carbon might be converted backwards and forwards in a very remarkable manner. He thought that rather bore on the fact which Dr. Stansfield referred to. With reference to the footnote relating to the allotropic varieties of iron, while he wished to pay all respect to Dr. Stansfield's very admirable paper, he thought that footnote should be somewhat qualified, out of respect to the carbonists. It read—"The allotropic varieties of iron are now well known." He thought they were theoretically well known, but he did not think there was any absolute proof of the existence of the three separate forms mentioned in the note. He would mention an old argument against the theory; that was, the fact of hardened steel being magnetic. If hardened steel contained the $\beta$-form of iron and was magnetic, he could not reconcile it with the footnote. He had read the paper with very much pleasure. It was somewhat abstruse, and perhaps, by means of a written communication, he might shortly add further information regarding experiments now in hand.

Mr. J. E. **Stead**, Member of Council, said the paper represented a very large amount of hard and careful work, followed by the "scientific use of the imagination." It was by using the imagination in this way that they gradually advanced. It seemed to him, however, that a great many of those deductions wanted verifying. It was highly probable that they were true, but, as Dr. Stansfield had pointed out, they were not in a position at the present time to dogmatise about the matter. He thought, however, that the following remark in the paper bordered on the dogmatic, viz., "Carbon will dissolve in molten iron just in the same way as common salt dissolves in water." He thought the better analogy would be to say that carbon would dissolve in molten iron just in the same way as sodium oxide dissolved in water. In this case they had sodium oxide first combining with the water to form a definite chemical hydrate, and this after formation dissolved in the water like salt. In like manner carbon first formed a definite compound or compounds, and such compound or compounds then dissolved like salt in water. He might be wrong, but at present he could scarcely see how the free carbon, which had a chemical attraction for metallic iron, could actually dissolve in iron and yet not be in combination with it. That was the chemist's difficulty. Dr. Stansfield's conclusion might be perfectly right, but he thought they wanted chemical verification. Chemists should work in that direction, and if Dr. Stansfield's and their President's conclusions were eventually proved to be right, it would be a marked instance of the value of the scientific use of the imagination, and also of the great significance and value of the cooling curves their President and Dr. Stansfield had been working at for so many years. It seemed a remarkable thing to himself and to many others, that a slight deviation in a cooling curve could indicate so much, for instance, whether the carbon atom in iron and steel might be in a monatomic, diatomic, or a triatomic condition. The curves were most useful in showing an internal change, but it was more difficult to state with certainty what the nature of the change really was. One instance of the scientific value of the thermal method so perfectly developed by their President and Dr. Stansfield had, during the last year, been confirmed in his (Mr. Stead's) laboratory. Sir William Roberts-Austen, in one of his reports on alloys to the Institution of Mechanical Engineers, had noted certain arrests in the cooling or solidifying of copper-tin alloys rich in tin. The inference was that these arrests indicated the falling out of definite chemical compounds. In his research by micro-chemical methods at Middlesbrough he had proved that such actually was the case. It was impossible for anybody to follow up this very delicate thermal investigation unless he was fitted up with the apparatus and provided with the proper conditions. If they in a Middlesbrough steelworks, for instance, were to try and follow such a research, they would find it very difficult; for so delicate is the galvanometer, every time a locomotive engine passed their laboratory or a cart moved down the street, arrests and erratic movements would result, and no useful or safe deductions could follow. If deductions were attempted, the arrests might be erroneously interpreted as indicating many allotropic modifications or definite compounds. Such researches must necessarily be followed out in laboratories situated in positions where all sources of error were eliminated. The underground vaults at the Mint were admirably adapted to that kind of research, and it was in such places as that, and under the direction of such careful manipulators as their President and Dr. Stansfield, that they must look for accurate and exact results. With reference to one other point: austenite, they were told, had got free carbon in it, but martensite had not; yet austenite was made into martensite by putting it into liquid air. How could the free carbon in austenite combine with iron at such a low temperature? It was very difficult to understand. It might be correct, but they wanted verification on that point.

Dr. A. STANSFIELD, in reply, said that the suggestion made by Mr. Snelus was very interesting, only there was this difficulty:—

It was desired, of course, to study the condition of the carbon when it was actually dissolved in the iron; but the method suggested by Mr. Snelus would appear—at first sight, at any rate—rather to enable one to study the condition of the carbon after it had separated out from the iron, which was quite a different thing. Of course, both conditions should be studied. Mr. Hadfield's remarks about the conversion of graphite into cementite were also extremely interesting. Mr. Hadfield objected to the statement that the allotropic varieties of iron were now well known, saying that their existence was not proved. The particular objection that he raised was that hardened steel was magnetic. That would be an objection if the iron in hardened steel necessarily contained iron in the $\gamma$-form; but Mr. Hadfield would notice that in the paper he (the speaker) had deliberately suggested that hardened steel contained iron in the $\alpha$-form, which would be quite in agreement with the facts. In regard to Mr. Stead, the discussion as to whether the carbon in molten steel combined with the iron or whether it did not, was, of course, a question on which something further might be said; but at the same time he thought there was quite as much to be said in favour of the view stated in the paper as there was to be said in favour of Mr. Stead's view. It was not known exactly in what way ordinary common salt did dissolve in water; so that the statement that carbon behaved in the same way did not quite define the position. With reference to austenite, the explanation mentioned in the paper was really that of Baron von Jüptner; and although it seemed to be quite possible that carbon in solid solution in iron might, on cooling down to a very low temperature, be enabled to combine with the iron and form cementite, yet he admitted that he had no very clear idea on the subject, and merely mentioned it as an explanation that had been advanced. Certainly some change took place; so they must be prepared to look for some action going on at that low temperature; and he did not know why the action should not be that of combination.

## *CORRESPONDENCE.*

Baron H. VON JÜPTNER sent the following communication:—The interesting paper of Dr. Stansfield offers not only a very clear insight into the present position of the solution theory of carburised iron, but possesses also many points worthy of close study, and the examination of which promises to still further advance the theory.

Such a point, for example, is the consideration of the circumstance that the molecular alterations of state which take place on the separation of crystalline subtances have exactly the same effect as the solidification of ordinary solutions, which is proved by Roberts-Austen's determinations of the latent heat of the modifications of iron at $Ar_3$ and $Ar_2$. The molecular size of the iron carbide $2(Fe_3C)$ and $2{\cdot}7(Fe_3C)$ therein calculated confirms the existence of polymerised iron carbides, and it is at least very probable that at $Ar_1$ a further polymerisation takes place.

To the remaining points which also invite further consideration here only a short reference can be made. Stansfield asks the question, whether in the cooling of fluid iron-carbon alloys pure iron or a solid solution is first separated?

According to Sauveur * the percentage of carbon in martensite fluctuates between 0·12 per cent. in very soft steel, quenched above the critical temperature, and 0·90 per cent. in hard steel. Steel with 0·09 per cent. carbon, quenched above $Ar_3$, contains 77 per cent. martensite and 23 per cent. ferrite. Above $Ar_3$, therefore, 0·12 parts of carbon can unite with 99·88 parts of iron, or in round figures 1 part of carbon with 800 parts of iron. The martensite cannot take up more ferrite, and, when the steel contains less than 0·12 per cent. carbon, the excess of the iron is present as free ferrite.

From this it follows according to Sauveur:—

---

* "The Microstructure of Steel."

| Temperature. | Saturation Point (in Martensite) of the | |
|---|---|---|
| | Iron for Carbon.[*] | Carbon for Iron. |
| Above $Ar_3$ . . . . . | ? | 0·12 % C. (1 C. to 800 Fe) |
| Between $Ar_3$ and $Ar_2$ . . | ? | 0·25 ,, (1 C. to 400 Fe) |
| Between $Ar_2$ and $Ar_1$ . . | ? | 0·50 ,, (1 C. to 200 Fe) |
| At $Ar_1$ . . . . . . | 0·90 % C. (1 C. to 110 Fe) | 0·90 ,, (1 C. to 110 Fe) |

These figures are confirmed by Osmond's observations[†] in which a steel with 0·14 per cent. C., 0·045 per cent. Si., 0·018 per cent. S., 0·01 per cent. P., and 0·19 per cent. Mn., gave—

| | Martensite. | Ferrite. | Approximate C. Contents of the Martensite.[‡] | C : Fe. |
|---|---|---|---|---|
| | | | Per Cent. | |
| Heated to 960° C., quenched at 670° (between $Ar_1$ and $Ar_2$) . | 14 | 86 | 1·0 | 1 : 99·00 |
| Heated to 960° C., quenched at 770° (between $Ar_2$ and $Ar_3$) . | 24 | 76 | 0·58 | 1 : 171·41 |
| Heated at 960° C., quenched at 820° (middle of $Ar_3$) . . | 46 | 54 | 0·30 | 1 : 332·33 |
| Heated and quenched at 1000° C. | 61 | 39 | 0·23 | 1 : 433·78 |
| Heated and quenched at 1340° C. | 90 | 10 | 0·16 | 1 : 624·00 |

Further study on very soft material at high temperatures must decide whether by the considerably lower carbon percentage in the immediate neighbourhood of the fusion-point, ferrite still separates, and *a priori* one would imagine that the ferrite line would pass through the fusion-point of pure iron. Still it is possible from the figures just given to arrive at another conclusion. Thus if we set out the differences of the ferrite percentages, we obtain—

---

[*] The saturation power of iron for carbon in martensite and austenite together is, according to the curve given by Roberts-Austen (Fifth Report of the Alloys Research Committee), approximately as follows:—

| | Per Cent. |
|---|---|
| 690° C. . . . . . . . . . . . . | 0·82 C. |
| 800° C. . . . . . . . . . . . . | 0·90 C. |
| 860° C. . . . . . . . . . . . . | 1·00 C. |
| 900° C. . . . . . . . . . . . . | 1·10 C. |
| 1000° C. . . . . . . . . . . . . | 1·07 C. |

With less than 0·12 per cent. carbon some ferrite remains unabsorbed on further heating (above $Ar_3$).

[†] Discussion on Sauveur's work.

[‡] These figures show that the solubility of the iron in carbon (or more correctly in the iron carbide) increases very considerably with increasing temperature.

| Temperature - difference. | | | Ferrite - difference. | | | Diminution of Ferrite per 1° C. |
|---|---|---|---|---|---|---|
| 770-670 | = | 100° | 86-76 | = | 10 % | 0·10 % |
| 820-770 | = | 50° | 76-54 | = | 22 % | 0·44 % |
| 1000-820 | = | 180° | 54-39 | = | 15 % | 0·08 % |
| 1340-1000 | = | 340° | 39-10 | = | 29 % | 0·08 % |

The ferrite diminution reaches a maximum at $Ar_3$, and decreases rapidly both at higher and lower temperatures, so that the possibility always remains that in very low carbon iron ferrite will first of all be separated.

The equation constructed by Heycock and Nevill for concentrated solutions unfortunately has been up to the present inaccessible to me, so that I can form no opinion upon its applicability.

The sentence, "The (fluid) eutectic consists of a mixture of graphite and of iron, containing about 2·2 per cent of carbon," I understand in connection with the above mentioned to mean that the fluid eutectic alloy of iron and carbon (such as a pig iron with 4·3 per cent. carbon) after solidification consists of 2·15 per cent. graphite, and an alloy of 95·7 per cent. iron, and 2·15 per cent. combined carbon. Here, of course, only an analysis of those alloys in which the graphite is determined apart from the separated temper carbon will help us, which, unfortunately in the present state of our knowledge, is not possible.

Still we can, relying upon our present knowledge, draw conclusions as to what takes place on the solidification of iron-carbon alloys and the solidification of the fluid eutectic alloy. Assuming that the fluid eutectic alloy consists of 4·3 per cent. of carbon and 95·7 per cent. of iron, or of 1 part of carbon to 22·25 parts of iron, and in low carbon alloys that the excess of iron would separate as ferrite, then we have—

| Total Carbon. | Eutectic Alloy. | Ferrite. |
|---|---|---|
| Per Cent. | Per Cent. | Per Cent, |
| 4·3 | 100·00 | 0 |
| 4·0 | 89·00 | 11·00 |
| 3·0 | 66·75 | 33·25 |
| 2·0 | 44·50 | 55·50 |
| 1·2 | 26·70 | 73·30 |

This, according to our experience of steel, is wholly incorrect; so we must, on the contrary, assume that in the rich carbon alloys not pure iron, but an iron-carbon alloy solidifies, whilst the eutectic alloy afterwards solidifies. But this iron-carbon alloy is apparently austenite, the quantitative composition of which unfortunately is not yet known. Since this by its further cooling passes into martensite, it must *at least* contain as much carbon as this latter, *i.e.* 1 part C. to 110 parts iron. But probably it contains, at least in rich carbon alloys, more, since otherwise it would not be possible to explain the separation of cementite in such kinds of steel. An approximate calculation from these facts cannot be made, since the carbon percentage of saturated martensite at higher temperatures is unknown.

If we interpolate in the curve on page 171 the three austenite points ascertained by Osmond, that is to say:—

| Per Cent. Carbon. | 0 per Cent. Austenite. | 50 per Cent. Austenite. |
|---|---|---|
| 1·0 | over 1000° C. | ... |
| 1·5—1·6 | 740° C. | 1140° C. |

it is at once apparent that, as I have already mentioned in another place, a straight line drawn through both the 0 per cent. austenite-points intersects the fusion-point of pure iron. Even if this be only accidental, yet the situation of this line shows that *the iron carbide is the more constant at higher temperature the more iron is present in excess,* a fact which, moreover, is very comprehensive, and further, *that the formation of iron carbide from its constituents, or the transformation of austenite into martensite, takes place through absorption of heat.*

Be this as it may, it is in any case very striking that *the end of the solidification curve of the eutectic alloy* (in the above-mentioned figure) *lies to the right of the* 0 per cent. = *Austenite line and not far distant from it.* This once more corroborates the suggestion that austenite is a solution of free carbon in iron, since only from such can graphite be separated.

If we assume that the 0 per cent. austenite curve runs practically as a straight line, and at any rate between the two points determined by Osmond (1·0 and 1·5 per cent. C.), this is approximately correct. We have for the composition of martensite the following:—

| Temperature. | Per Cent. C. | Parts of Iron per 1 Part of Carbon. | Per Cent. $Fe_3C$. |
|---|---|---|---|
| 1130° C. | 0·86 | 115·28 | 12·90 |
| 1040° ,, | 1·00 | 99·00 | 15·00 |
| 1000° ,, | 1·07 | 92·46 | 16·05 |
| 930° ,, | 1·20* | 82·33 | 18·00 |
| 690° ,, | 0·82 | 120·95 | 12·30 |

Thus we see that the solubility of the carbon, or of the carbide, begins to rise at 690° C., reaches a maximum about 930° C., and then again falls.

Under the supposition that iron at its fusion-point contains only austenite but no martensite, from an analysis of Saniter's,† according to which molten iron carbide with only 0·05 per cent. S. and of 0·15 Mn. after slow cooling contained:—

| | Per Cent. |
|---|---|
| Graphite | 3·05 |
| Combined carbon | 1·22 |
| Total | 4·27 |

[which composition corresponds to the eutectic alloy], we calculate for austenite at 1130° C. the following composition:—

| | Per Cent. |
|---|---|
| Combined carbon | 1·27 |
| Iron | 98·73 |
| Total | 100·00 |

(To one part of carbon there is 77·74 parts of iron.)

If we denote by a series the total carbon present as C., the carbon existing in the austenite, martensite, and graphite as $C_a$, $C_m$, and $C_g$, we have $C_a + C_m + C_g = C.$; $77{\cdot}74\ C_a + 115{\cdot}28\ C_m + C_g = 100$; and from this $C_m = 2{\cdot}66 - 2{\cdot}07\ C. + 2{\cdot}04\ C_g$.

Now $C_m$ is for steel with 1·2 per cent. at 1130° C. $\frac{0{\cdot}86}{2} = 0{\cdot}43$ per cent. (since, if the 50 per cent. austenite curve has been correctly drawn, *i.e.* goes through the fusion-point of pure iron,* it contains 50 per cent. martensite.)

---

* This may possibly, in consequence of a small separation of graphite, be somewhat too high.

† *Journal of Iron and Steel Institute*, 1897, No. II., p. 115.

From this we get—

$$0{\cdot}43 = 2{\cdot}66 - 2{\cdot}07\ \mathrm{C.} + 2{\cdot}04\ \mathrm{C_g.}$$
$$= 2{\cdot}66 - 2{\cdot}48\ \mathrm{C.} + 2{\cdot}04\ \mathrm{C_g.}$$

and from this—

$$\mathrm{C_g} = \frac{0{\cdot}25}{2{\cdot}04} = 0{\cdot}12 \text{ per cent.}$$

As a matter of fact, the eutectic curve lies somewhat below 1·2 per cent. carbon, so that evidently a small separation of graphite must have taken place.

Whilst this eutectic curve runs from right to left until in the neighbourhood of the 0 per cent. = austenite curve, the separation curve of free cementite shows, on the contrary, the remarkable fact that it, so far as it has been actually observed, ends only slightly to the right of that point at which the 50 per cent. martensite and 50 per cent. austenite of Osmond was proved to do. Does it not appear probable, then, that a further separation of carbide would furnish no further recalescence-point, since the transition of austenite into martensite in the course of the cooling down takes place quite gradually, and on this ground the separation of the excess of iron carbide can also only proceed gradually? The course of events may be considered to run as follows:—Austenite contains at 1130° C. about 1·27 per cent. carbon, whilst martensite only contains 0·86 per cent. C. Now, when by continued cooling a part of the austenite is transformed into martensite, the saturation power of the solution for martensite rises a little until 930° C.; but since the carbon thus introduced (of course as carbide) is above this amount, a part of the carbide therefore (probably polymerised) must separate out.

It is self-evident, then, that in the cooling of iron all the alterations in the conditions of a solution and otherwise can undergo modification by the rapid cooling of the iron due to the internal pressure set up in the interior of the metal.

Collecting the above arrived-at conclusions we have:—

1. The molecular formula of iron carbide at $\mathrm{Ar_3}$ is $2(\mathrm{CFe_3})$, at $\mathrm{Ar_2}$ $2{\cdot}7(\mathrm{CFe_3})$. The polymerisation of this compound appears therefore to be settled.

---

* This must be the case if the suppositions that the 0 per cent. austenite curve goes through this point, and that molten iron contains only free dissolved carbon be correct.

2. Whether in a very low carbon iron alloys, pure iron or an iron-carbon solution first solidifies, remains undecided, as also does the question whether in fluid iron a two-atomic or a smaller carbon molecule is dissolved.

3. The saturation power of carbon (or more correctly of iron carbide) for iron increases with the temperature, but even at 1340° C. not more than 1 part of carbon to 624 parts of iron is dissolved.

4. Consequently in iron low in carbon the quantity of ferrite decreases with the temperature. This decrease takes place unequally, and reaches a maximum about $Ar_3$.

5. The saturation power of iron rises from 690° to 930° C, and then decreases with further rise of temperature.

6. The discontinuity of the fluid eutectic curve at and about 1·2 per cent. carbon appears to be explicable by the transition of austenite into martensite, which occurs with decreasing percentage of carbon.

7. Inversely, the disappearance of the separation curve of cementite can be explained by an increase in the quantity of carbon corresponding to the conversion of martensite into austenite, assuming a constant temperature.

Mr. A. McWILLIAM sent the following communication:—The title of the paper and the name of the author would lead one to expect a judicial and impartial review of the solution theory of carburised iron, clearly summarising the case for and against, and ending with the author's own view of the matter. Disappointment must be great, therefore, on finding it to be a forensic advocacy of one side only. Dr. Stansfield, in the discussion on a paper on "Diffusion of Elements in Iron" read before the Institute last May by Professor Arnold and himself, said "that he had no prejudice against supposing that the carbon might be combined with at least three atoms of iron in the solution." The following quotation from their reply should be considered:—"Dr. Stansfield's view of the matter was interesting; 'it might also be described as a carbide of iron dissolving the iron.' Add to that that the solution in a pure iron and carbon steel was always of an absolutely definite composition, and the difference between them was very small indeed. They might assure Dr

Stansfield that the composition found was not the result of chance in two or three experiments, but had been abundantly corroborated in dozens of cases at the University College; and they were sure that Dr. Stansfield would be delighted with the wonderful delicacy of this, as shown under the microscope even during the examination of this diffusion series, slightly over the 0·9 per cent. carbon showing cementite, and very slightly under showing grains of ferrite."

The analogy between steel and saline solutions might hold when the steel was taken as carbide of iron dissolved in iron, but not when it was assumed to be elementary carbon dissolved in iron.

That the magnetic properties of hardened steel should be due to the admixture of α-iron in it seemed a strange explanation, when, among other things, the polished and etched surface of such a steel as was usually made into magnets showed under the microscope a homogeneous field.

The note in the paper stating that the allotropic varieties of iron were now well known was distinctly misleading, as the allotropic theory, as originally advanced by Mr. Osmond and introduced by Sir William Roberts-Austen, had no well-defined connection with either the present allotropic theory or the solution theory, but boldly stated that the hardening of steel was due, not to carbon or a carbide, but to β-iron, an allotropic modification of iron of flint hardness,—a theory now generally discredited, although it had not actually been withdrawn by its author. "β-iron is not magnetic, but does not dissolve cementite." This statement meant that carbon would not pass into pure iron until after the Ar3 change at 900° C., a statement which was against the facts given in the paper on diffusion already quoted, viz.: "In six hours pure iron took up 0·11 per cent. C at 785° C.," a fact to which Dr. Stansfield deemed it wise not to refer.

It would be very much appreciated by many metallurgists with whom he had conversed if Dr. Stansfield would in his reply give a statement up to date of the names and known properties of the alleged allotropic forms of iron, especially with reference to their mechanical and magnetic properties, their approximate hardness, their appearance under the microscope, and their power of dissolving carbon.

Dr. **Stansfield**, in reply to the correspondence, wrote that he had thought it best to restrict himself to an explanation of the solution theory of carburised iron apart from the other theories on the subject.

A thorough examination of the evidence upon which the solution theory rests might, perhaps, have been expected in the present paper, were it not for the valuable contributions which had already been made by H. Le Chatelier and by Baron von Jüptner. He considered that it would be better to give a simple and entirely uncontroversial statement of the solution theory, and to discuss in a separate paper the extent to which this theory appeared to be in accord with the experimental facts.

The diffusion of carbon in pure iron at 785° C., to which Mr. M'William referred, was easily explained on the supposition that his "pure iron" contained initially a trace of carbon. Professor Arnold stated that it contained 0·05 per cent. of carbon, and this would indicate that at 785° C. about one-seventh of the iron might be in the $\gamma$ state, containing $Fe_3C$ in a state of solid solution, and thus affording a fairly good path for further diffusion of carbon. When the diffusion had once begun, the amount of iron carbide solution would increase, and this would render the process of diffusion more and more easy. This view was strongly supported by Professor Arnold's own experiments, which showed that, at the same temperature, diffusion of carbon was facilitated by the initial presence of a moderate amount of carbon in the iron; provided, of course, that the amount of carbon present was not allowed to approach the saturation point. The author referred to this in the discussion on Professor Arnold's paper at the May meeting,* and had also fully explained why pearlite in pure carbon steel had always the same composition.

The meaning of the three critical points, $Ar_1$, $Ar_2$, and $Ar_3$, was not dealt with so fully as it deserved, but a short consideration of the allotropic changes of iron containing less than 0·34 per cent. of carbon would be found on page 177.

The contribution of Baron von Jüptner would constitute a paper in itself, and deserved more attention than could be given to it at present. It would be noticed that he confirmed the author's view that in rich carburised iron the first portion to solidify was not pure iron, but contained some carbon dissolved in it. Baron von Jüptner's observations on the amount of free ferrite in low carbon steels at high temperatures were of great importance in connection with the solution theory, because, as explained in the paper, the solution theory indicated the complete solubility of ferrite in low carbon steels at temperatures above the line G O S (see fig., p. 171). Osmond and others had shown that steels quenched from temperatures above this line contained small amounts of undissolved ferrite, and it would be necessary to decide whether this was due to an insufficiency of time for the complete solution of the ferrite, or whether a modification of the theory might be required in the direction indicated by Baron von Jüptner.

---

* *Journal of the Iron and Steel Institute*, vol. lv. p. 116.

The PRESIDENT said it really was very important, and he hoped it would be understood, that they were in a position, at least, to argue about the number of atoms which occurred in the molecules of carburised iron. They knew the lowering of the freezing-point produced by the presence of carbon, and they could, at least, think and talk about the atomic grouping. That really was a step of great importance, and one which five years ago they would hardly have thought was so near. That, he thought, was all that they could say about it at the moment. No one wished to dogmatise on the matter. He was sure they would give a hearty vote of thanks to the author.

The vote of thanks was cordially agreed to, and the following paper was read:—

# THE RELATION BETWEEN THE STRUCTURE OF STEEL AND ITS THERMAL AND MECHANICAL TREATMENT.

BY ALBERT SAUVEUR, BOSTON, U.S.A.

## I. CHANGES OF STRUCTURE BROUGHT ABOUT BY HEAT TREATMENT.

THE changes of structure, with their resulting changes of physical properties, brought about in carbon steel by heat treatment, may, I believe, be summarised in the following propositions:—

I. When a piece of steel, hardened or unhardened, is heated to the temperature *W*,* all previous crystallisation, however coarse or however distorted by cold work, is obliterated and replaced by the finest structure which the metal is capable of assuming,† the structure of burnt steel, which cannot be effaced by such treatment, being the only exception.

---

* In these propositions the letter *V* indicates the temperature at which hardening carbon is changed to cement carbon during the slow *cooling* of steel, a change which is accompanied by a retardation in the rate of cooling, indicating an evolution of heat, sometimes so considerable as to produce an actual rise of the sensible temperature, a recalescence, of the cooling metal. In other words *V* represents the temperature of the critical point commonly known as the point of recalescence. The temperature *V* varies somewhat with the carbon content, being lowest in the most highly carburetted compounds. In medium hard and in hard steel it is generally situated between 625° and 700° C., and covers a range of some 20° to 30°. In very soft steel the transformation occurs at a higher temperature. In steel containing very little carbon it is, of course, hardly detectable, and is not found in carbonless iron.

The letter *W* indicates the temperature at which takes place the opposite phase of the same phenomenon, *i.e.* the passage of cement carbon into hardening carbon during the *heating* of steel, which transformation is accompanied by a retardation in the rate of heating, indicative of an absorption of heat. The temperature *W* is generally some 30° higher than *V*, and often covers a range of some 25°.

The symbols *V* and *W*, first proposed by Brinell, have been selected here in preference to $Ar_1$ and $Ac_1$, now more generally used, merely on account of their greater simplicity.

† It has been stated by Coffin that in the case of soft steel (containing 0·20 per cent. carbon) a single heating to *W* breaks up only partially a pre-existing coarse crystallisation, a second reheating to that temperature being necessary to obliterate it altogether. This point should be further investigated.

Some steel castings also are said to require more than one heating to *W* to assume the finest possible structure.

II. When a piece of steel, hardened or unhardened, after being heated to the temperature *W*, is allowed to cool slowly, it retains the fine amorphous-like structure which it had acquired at that temperature. It possesses then the finest structure which unhardened steel is capable of assuming.

III. When a piece of steel, hardened or unhardened, after being heated to the temperature *W*, is suddenly cooled from that temperature, by quenching it in cold water for instance, it is fully hardened,* and retains the fine amorphous-like structure acquired at that temperature. The metal possesses then the finest structure which hardened steel is capable of assuming.

IV. When a piece of steel, hardened or unhardened, is heated to a temperature above *W* and allowed to cool slowly and undisturbedly, the metal, whose crystallisation had been obliterated by its passage through *W*, crystallises again, the crystals or grains increasing in size until the temperature *V* is reached, below which there is no further growth. (See Appendix I.)

*Corollary to III. and IV.*—When a piece of steel, after being heated to a temperature above *W*, is allowed to cool to *W* and then quenched, it will be fully hardened, but its structure will be coarser than if it had been quenched from *W* without having been previously heated *above* that temperature. (See Appendix I.)

V. The higher the temperature above *W* from which the steel is allowed to cool undisturbedly, the larger the grains.

VI. The slower the cooling from a temperature above *W*, the larger the grains.

*Corollary to V. and VI.*—Pieces of steel finished at a temperature above *W* will have a coarser grain in those parts which have been finished hottest, and where subsequent cooling has been more gradual, *i.e.* the central portions, or portions further away from the cooling surfaces.

---

* It is evidently meant here, and in all similar references, that after heating to the above temperature, the steel under consideration will acquire all, or practically all, the hardening power which that particular steel is capable of assuming, no further increase of hardness resulting from quenching at a higher temperature. Its absolute degree of hardness will, of course, depend upon its carbon content, rate of cooling, and the presence of other impurities; in the case of the softest steels, the increase of hardness may be very, if not altogether, inappreciable. Very low carbon steels, moreover, do not seem to acquire, in its entirety, during *W*, whatever hardening power they possess, it being necessary for that purpose to heat the metal to a higher temperature, *i.e.* pass the upper retardations.

VII. When a piece of steel, hardened or unhardened, is heated to a temperature above *W* and suddenly cooled, it is fully hardened, but its structure will be coarser than when quenched after having been heated to *W*. (See Appendix I.)

VIII. When a piece of unhardened steel is heated to a temperature below *W* and quenched or slowly cooled from that temperature, no change takes place in its structure. (See Appendix II.)

IX. When a piece of hardened steel is heated to a temperature below *W*, some of its hardening carbon is changed spontaneously into cement carbon, and the metal is thereby softened. The tendency of the hardening carbon to pass into the cement condition increases with the temperature, and is the greatest at the temperature *V*. This transformation, however, is not accompanied by any change in the dimensions of the grains. (See Appendix III.)

These propositions are for the most part illustrated graphically in Fig. 1, in which I have adopted Brinell's mode of representation.

## II. CHANGES OF STRUCTURE BROUGHT ABOUT BY WORK.

We must at the outset consider two kinds of work: hot work and cold work. By hot work I mean work performed above the critical range, *i.e.* above *W*; by cold work is meant work performed below the critical range, *i.e.* below *V*. The work done between *V* and *W* will be cold work if the temperature of the metal has just been raised from *below V*, and it will be hot work if its temperature has just been lowered from *above W*. This is shown in Fig. 2, in which the range of temperature corresponding to hot work is indicated by a heavy black line, and that corresponding to cold work by a dotted line. The dotted and black lines considered collectively represent the temperature of a piece of steel heated from the atmospheric temperature to a temperature above *W*, and then cooled again to the atmospheric temperature.

If the metal be worked at any time during this thermal treatment, it will be cold worked if the corresponding temperature be represented by a point of the dotted line, and hot worked if it be indicated by a point on the full black line.

The effect of work upon the structure of steel may be summarised in the following propositions:—

I. While steel is being worked it does not crystallise (provided, of course, the working of the metal is sufficiently vigorous to affect all parts of the mass).

II. Hot work *as such* has no influence upon the structure of the metal. *Indirectly,* however, by retarding crystallisation until a lower temperature is reached, it may influence its structure most decidedly; but the same results could be accomplished by heat treatment alone, *i.e.* by reheating the unworked metal to the temperature from which the worked piece was allowed to cool undisturbedly.

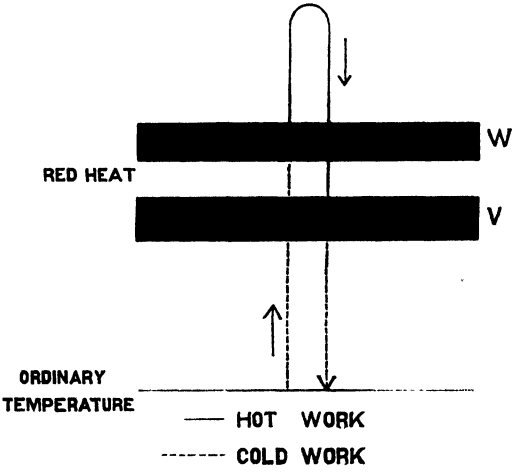


FIG. 2.

*Remark.*—A certain amount of work is, of course, necessary to expel the slag, close blow-holes and other similar irregularities, and otherwise render the piece sound; but once this is accomplished, further work will not improve the structure, *except indirectly as stated above.*

III. Cold work distorts the grains or crystals of steel, flattening them and elongating them in the direction of the forging or rolling.

IV. The lower the temperature the more pronounced the effect of cold working.

*Remark.*—The structural distortion caused by cold working, with its accompanying alterations of the physical properties of the metal, may be removed by heating the metal to *W* (see Proposition I.).

## III. CONCLUSIONS.

From the above considerations, we may draw the following conclusions of industrial interest:—

*Finished Pieces of Unhardened Steel.*—Since it seems to have been conclusively shown that the smaller the grains of the metal, the more ductile and tough it will be, it is evident that we should endeavour to impart such a structure to all finished pieces, and as the finest possible structure results from heating to *W*, we naturally infer that every finished piece of unhardened steel, in order to be in the best possible condition, should, as a last treatment, be heated to *W*.

While, for numerous reasons, such treatment cannot always be applied, being, indeed, in many instances, altogether impracticable, nevertheless manufacturers should endeavour to approach this *desideratum* as much as is consistent with other conditions and requirements of production. Forged or rolled pieces should be finished as near the temperature *V* as possible, since finishing them at a temperature much above *V* leads to the development of a coarse structure during subsequent undisturbed cooling, while if they be finished below *V* they will suffer from the effects of cold work.

The problem, however, is further greatly complicated by the fact that thick pieces cannot be finished at a temperature uniform throughout, the differences of temperature between the central portions and the outside increasing rapidly with the cross section of the piece. If it be finished at a temperature above *V*, the whole mass will begin to crystallise during subsequent cooling, but the interior, being hotter and cooling more slowly, will have a larger grain than the outside portion; the resulting structure will be far from uniform, and the physical properties of the finished piece in its various parts will also necessarily lack uniformity, as may be ascertained by testing specimens cut from different regions. If the outside or thinnest parts have reached *V* when the piece leaves the forge or the finishing rolls, the central portions may be considerably above that temperature, and may assume a coarse crystalline structure; while if the working be continued until the interior of the piece has reached the temperature *V*, the thinnest portions may be much below that temperature and suffer from the effects of cold working.*

Uniformity of structure (and therefore of physical properties) in all parts of a worked piece of steel, together with freedom from distortion caused by cold work, can only be secured by reheating *throughout* to the temperature *W*; and while such treatment, as already stated, is impracticable in many cases, besides necessitating the use of pyrometers, it remains true that with a clear understanding of the effect of heat treatment and of work upon the structure of the metal, each manufacture has it in its power to improve the quality of its product.

In the manufacture of costly pieces of steel, when large outputs, necessitating the highest possible speed of production, is not the all-important and all-absorbing factor—in the production of armour-plates, for instance, and of expensive forgings—the metal may be treated on these scientific lines, and the highest efficiency secured.

*Annealing.*—There seems to be considerable difference of opinion with regard to the meaning of the term "annealing," and still more concerning the proper temperature to which the metal should be heated, and the conditions which should prevail during the operation. To the mind of some steel-workers, annealing conveys the idea of a mere heating to a temperature sometimes considerably below, and sometimes considerably above, *W*. For others it implies a prolonged heating at a temperature varying from a barely red to a very bright red or even yellow heat. Some workers cool their steel very slowly in the annealing furnace; some more rapidly in the air; others still quenched the metal after reheating to a dull red heat. Finally, the metal is heated in boxes or pipes with or without packing material, or it is heated in the open furnace without any protection.

---

* A familiar instance of such heterogeneousness of structure is found in steel rails whose structure frequently reveals the fact that the web and extremities of the flange have suffered from cold work, while the centre of the head exhibits a well-developed crystalline structure, indicative of undisturbed cooling from a temperature above *W*.

In short, it is seen that any reheating, followed or not by slow cooling, *whose aim is to soften the metal and increase its ductility,* might quite properly be called annealing, for I see no sharp line of demarcation between tempering and annealing. Just where the softening and toughening operation should cease to be called tempering to assume the name of "annealing," can only be decided arbitrarily. Tempering should be considered as a species of annealing.

It is not the writer's desire to formulate any dogmatic rules which should be followed in carrying out this most important operation, but merely to inquire into the changes of physical properties which we desire to bring about in the annealing of steel, believing that such inquiry, together with our knowledge of the effect of heat treatment upon the structure of steel, should naturally lead us to the adoption of the most desirable treatment.

The changes in the physical condition of the metal which we desire to bring about by annealing are several in number, and of course depend upon the treatment to which the metal has been previously subjected. I believe that they may be summed up as follows:—

I. Softening of the metal (decrease of its mineralogical hardness), by obliterating the increase of hardness conferred by previous hardening or by cold working.

II. Increase of ductility, by obliterating the brittleness caused by previous hardening or cold working, and also by cooling stresses (which always occur during the cooling of large castings or forgings from a high temperature).

III. Obliteration of coarse crystallisation caused by a previous undisturbed cooling from a temperature higher than *W*, and of structural distortion produced by cold working, imparting to the metal the finest possible structure which it is capable of assuming.

In short, in annealing steel our purpose is to render the metal as soft, tough, and ductile as possible, and to do so by decreasing the elastic limit and tensile strength only of such, so to speak, abnormal increments, as were acquired through hardening and cold working.

From our previous considerations it is evident that to accomplish this in the most effective manner the metal should be reheated throughout to *W*, and slowly cooled from that temperature, maintaining it a sufficient length of time at the temperature *V* to assure a complete change of the hardening carbon into cement carbon. By heating the metal to *W* all previous coarse crystallisation or distortion is obliterated and replaced by the finest possible structure. In cooling slowly through the *V* range, its hardening carbon passes back into cement carbon, but as the complete transformation requires time, it is desirable to keep the metal for some time at that temperature. After such treatment the steel will undoubtedly be in its softest and most ductile condition.

The writer is well aware that the above conclusions are somewhat at variance with those of Brinell, who advises heating to *V* in annealing steel. As already stated, the writer finds that reheating to *V* for a sufficient length of time will cause all the hardening carbon that may be present in the steel to be changed into cement carbon; it may possibly also remove all cooling stresses, so that such treatment undoubtedly greatly increases the softness and ductility of the metal. It does not, however, impart to it as fine a micro-grain as it is capable of assuming, and consequently the metal, after being reheated to *V*, does not possess *all* the ductility that could be its own.*

*Hardening and Tempering.*—It is almost superfluous to state here, that in order to harden steel, and at the same time preserve the best structural arrangement, the metal should be heated to *W* and then quenched, without allowing the temperature to rise above *W*. This rule is quite universally followed, and although smiths seldom use pyrometers, some of them become such experts in judging the temperature of the metal by the colour, that it is probable that the majority of their pieces are, at the instant of quenching, very near *W* indeed, or at the refining temperature, as they properly call it.

The temperature of tempering is also very universally regulated by the colour of the metal, and generally with great skill and accuracy.

The use of pyrometers in connection with the hardening and tempering of steel should nevertheless be commended, as it removes all uncertainty, secures uniformity of treatment, and may be the means of avoiding the destruction in the quenching bath of many costly pieces.

---

* If the steel has just previously been heated to *W*, then, of course, reheating to *V* (for the purpose of removing hardening carbon) will be sufficient to render the metal as soft and ductile as possible.

It is customary, the writer believes, to quench the metal (merely for convenience ?) after it has been heated to the proper temperature for tempering, instead of allowing it to cool slowly from that temperature. It is, however, probable that, if it be left to cool slowly, its softness will increase, since the change of hardening carbon into cement carbon, which is arrested by the sudden cooling, will continue a while longer, at any rate, if the steel be slowly cooled.

## APPENDIX I.

The fact that all crystallisation previously existing in the metal is obliterated during the change occurring at *W* has been repeatedly demonstrated, and, so far as I know, is not contested by any metallurgist. It is also admitted by all, I think, that steel crystallises while *cooling* from a temperature above *W*. There is, however, a widespread belief that the metal does not retain, until the cooling begins, the fine amorphous-like structure acquired at *W*, but on the contrary begins to crystallise immediately after the temperature *W* is passed, and continues to do so *while its temperature is rising.* This view is held by such eminent metallurgists as J. A. Brinell and H. M. Howe ; while D. Tschernoff, on the other hand, took the stand, long ago, that steel does not crystallise while its temperature is rising.

The statement that steel does crystallise while its temperature is rising is certainly opposed to the very nature of crystallisation, and on that account we should naturally feel reluctant to accept it without more conclusive evidence. Steel above the critical range has often been likened, and on very good grounds, to a solution—a solid solution, of course. The crystallisation of a solid solution, as well as of a liquid solution, consists in the crystallisation or segregation of its structural components taking place at certain temperatures and in a certain order. Can the constituents of a liquid solution crystallise—in other words, can a solution solidify when its temperature is rising? The supposition is evidently absurd. Can the structural components of a solid solution segregate, then, on a rising temperature? Does not the same law apply in both cases? Is not a falling temperature a necessary condition to the formation of crystals? During undisturbed cooling cohesive attraction, the force to which crystals owe their formation, acts powerfully, causing them to grow, while during heating cohesive attraction is opposed more and more by the rising temperature. Is there a single instance of a solution, or for that matter of any substance, crystallising while its temperature is rising?

The contention that steel does crystallise above *W*, while its temperature is rising, is based upon the fact that when a piece of steel is quenched at a temperature above *W* its structure will be the coarser the higher the quenching temperature—from which it is inferred that its grains must have grown during the *heating previous to quenching.* It should be remembered, however, that it takes an appreciable time for a piece of steel, especially for its central portions, to cool to *V.* If the piece be large, the length of time required will be very considerable indeed, and may be such that its centre will not be hardened at all. Has not the growth of the resulting grains taken place during the *cooling* of the mass, however rapid, rather than during its heating, seeing that the cooling is far from being sudden and increases in length very rapidly with the cross section of the quenched piece? I find that the larger the cross section of the piece, the larger will be its grains (because the slower the cooling?), while if the latter had formed during heating there should be, it would seem, little difference in structure between a large and a small sample, unless indeed it be argued, as it reasonably might, that the larger grain of the larger piece is due to the slower *heating* of that piece.

It has not, however, by any means been shown that if the cooling from a high temperature could be sufficiently sudden the structure would not be as free from coarse crystallisation as if it had been quenched upon reaching *W.*

Although I am inclined to share Professor Tschernoff's view, I frankly admit that no conclusive evidences have been presented on either side, and it is to be hoped that this question will soon be definitely elucidated.

If it should be shown beyond doubt that steel does indeed crystallise on a rising temperature, the phenomenon could not, I think, properly be called crystallisation—granulation would probably be a more correct term.

I hope to be able shortly to present some further experimental evidence bearing upon this point.

## APPENDIX II.

In Proposition VIII. it is stated that when a piece of unhardened steel is heated to a temperature below *W* its structure remains unchanged. Mr. Stead, however, has shown, in a recent and very important paper,* that when a piece of iron or of *very soft* steel is subjected to a *prolonged* heating at a temperature between 600° and 750° C. (therefore below *W*) its structure becomes coarsely crystalline. Here we apparently meet, therefore, with an exception to our proposition. It should be noted, however, that it is only the *softest* brands of steel whose structure is thus altered at a temperature below *W*. Mr. Stead has repeatedly failed to produce a change of structure under such condition in steel containing over 0·20 per cent. of carbon. Indeed, in the experiments which he describes, I find no instance of a coarse crystallisation having been produced below *W* in steel containing over 0·11 per cent. of carbon. The exception is therefore apparently confined to a very narrow range of the carbon steel series. It should also be remembered that a prolonged heating is required in order to produce this growth of the grains; a mere heating to a temperature below *W* leaves the structure of this nearly carbonless iron unaltered.

The metal which Mr. Stead finds to crystallise below *W* is practically a mass of ferrite, and he has thus demonstrated that when *ferrite* is heated for a long time at a temperature between 600° and 750° C., it develops a coarse crystallisation, or perhaps more properly, granulation. There is no apparent reason to suppose that ferrite will not always crystallise in this way, when subjected to such treatment, whatever the carbon content of the steel. The amount of ferrite present in steel, however, rapidly diminishes with increase of carbon. Steel containing over 0·80 per cent. of carbon does not contain any ferrite, and should therefore remain, as it does, unaffected when submitted to the above treatment. Steel containing less than 0·80 per cent. of carbon is made up of grains of pearlite surrounded by membranes of ferrite. The coarse crystallisation of these membranes of ferrite, supposing that it does occur below *W*, does not alter the dimensions of the grains of the metal, and has probably little, if any, influence upon its physical properties. Iron and very low carbon steel, on the contrary, are made up of grains of ferrite, and a coarse crystallisation, or a change of structure of this constituent, means corresponding changes in the structure of the metal itself. This appears to be the explanation of the notable difference, shown by Mr. Stead, between the behaviour of carbonless or slightly carburetted iron and more highly carburetted steel, when subjected to the thermal treatment described above.

---

* *Journal of the Iron and Steel Institute*, 1898, I. and II.; *The Metallographist*, October 1898 and April 1899.

Finally, it should also be noted that the alteration of the structure of ferrite requires time, while the obliteration of the structure assumed by pearlite appears to be dependent only upon the proper degree of heat (*W*), and takes place simultaneously with the passage of its carbon from the cement to the hardening state.

## APPENDIX III.

In his most valuable chart showing the changes of fractures brought about by heat treatment in steel containing 0·75 per cent. of carbon, Mr. Brinell states that if a piece of steel which has been hardened above *W*, and which has, therefore, a coarse structure, be reheated to *V*, and maintained at that temperature for a sufficient length of time, all its hardening carbon will be changed into cement carbon, and its structure will be as fine as if the piece had been reheated to *W*.

The microscopical examination of a limited number of samples of steel subjected to the above treatment appears to oppose the second portion of Mr. Brinell's proposition, for while the writer finds that a prolonged reheating at *V* causes practically the whole of the carbon to pass back into the cement state, the size of the grains of the metal seems to remain unaltered. The carbon change appears to take place *in situ*, within each individual grain, without affecting its dimensions. It is the writer's intention to examine a larger number of specimens containing various amounts of carbon and reheated to *V*, for different lengths of time, and he hopes that his remarks will induce others to investigate the question.

Mr. Brinell, the writer thinks, based his propositions upon the appearance of the *fracture*, not of the microstructure, and, *judged by its fracture*, the annealed metal may appear to have a smaller grain, because the fracture of the grains of pearlyte, as produced by this tempering process, may be finer and more silky than that of the martensite grains resulting from quenching at a temperature above *W*, although the micro-grains would in both cases have the same dimensions.

## *DISCUSSION.*

The PRESIDENT said that there were few more accurate observers, or thinkers, or writers than Mr. Sauveur, and they would, therefore, be glad to hear any discussion of his paper.

Mr. RIDSDALE said that Mr. Sauveur's paper was very interesting to him, and dealing as it did with "carbon steel," it was important to note that many of the same rules held good for this quality which he himself had described for *soft* steel or ingot iron in his own paper given at the same meeting. For instance, he had drawn special attention to the breaking up effect on the grain of reheating, both in his present and former paper, and had shown photographs illustrating it, and this was stated by Mr. Sauveur in Proposition I. to apply to carbon steel also. Propositions V. and VI. also held good for soft steel. There was, however, one term employed by Mr. Sauveur to which, notwithstanding the explanation given of what he meant by it, he (Mr Ridsdale) objected, as liable to lead to confusion and misconception, viz., the term "cold work" as applied to "work done between *V* and *W*" on p. 197 and elsewhere. The temperatures referred to throughout as "cold work" were all above 600° C., and since this was dull red heat, the term was a misnomer. There were commercial products known as "cold rolled," "cold drawn," &c., which were prepared by subjecting the material to work at *ordinary atmospheric temperatures* without any extraneous heat, and in this connection he had himself used the term "cold worked" for samples worked *below* blue heat, whilst the cold work referred to by Mr. Sauveur was in all cases considerably *above* blue heat. He therefore drew special attention to the point, and trusted the term would not be used except in the proper connection. The whole paper put forward in a most valuable manner the plea for recognition by users of steel of the effect of heat treatment brought about by the conditions under which it was worked, and the modification or supplementing of them when necessary in accordance with the light of recent investigation. Reference was made by Professor H. M. Howe to a bar of steel which he heated rapidly to

bright white heat, and he did not find the centre *coarser* than the outside. He (Mr. Ridsdale) himself had in his paper and by photographs at the same meeting abundantly shown that under such circumstances this was not to be expected, as it was usual, if there was not an actual carbonless band formed, for there to be at least a considerably *coarser* structure on the *outside* than at the centre.

Mr. R. A. HADFIELD, Member of Council, said the paper was exceedingly interesting—in fact, it was one of the most important they had had at that meeting; but he could not help thinking that some of the definitions were wanting in clearness. For example, in his second paragraph Mr. Sauveur said, "When a piece of steel, hardened or unhardened, is heated to the temperature *W*." What did he mean by that expression? The word "steel" was so very wide that he was sorry Mr. Sauveur had not more clearly defined what was the temper of the steel he had in mind. There was no doubt whatever that the point *W* was not the same in hard as in soft steel—in fact, that there was much greater difference than was commonly supposed. Besides, too, in hard steel, that is, high carbon steel unhardened, the desired fine structure was a function not only of temperature, but of time, which a number of experimentalists in various recent contributions to this important question did not seem to realise. The importance of very clearly defining exactly what was meant in a paper like this was shown by the excellent advice which Mr. Sauveur himself gave regarding the treatment of finished pieces of unhardened steel. But the same heat treatment to the point *W* of all steel would be a fatal mistake; therefore the desired *W* temperature for each grade of steel should be given. They might have, in ordinary carbon steel, one grade up to about 0·2 per cent. of carbon; the next would be over 0·25 and under 0·50 per cent; the next 0·6 to 0·9, and then a grade above that of 1·0 per cent. and upwards. Each of these grades would probably be found to require a *W* temperature of its own, and these again were more or less modified by the character of the other constituents present besides carbon. He only criticised Mr. Sauveur's remarks with the view of bringing out more clearly the very valuable portions of his paper.

It was the extraordinary sensitiveness to heat changes of different tempers or grades of steel which made the whole question of structure such an exceedingly difficult one to determine. General statements were quite insufficient when dealing with the marvellously complex body known as steel. It was to be hoped, therefore, that Mr. Sauveur, when completing his paper, would clearly define in each of his references the particular kind of steel to which he was referring, giving the analysis and the whole history as far as practicable of the specimen in question. Without that, they would be apt to form wrong impressions. He thought Mr. Stead, who had made so many examinations of steel in this way, would agree with him. It was for this reason that Brinell's researches had been so exceedingly valuable. Wherever Brinell experimented, he most clearly stated the exact kind of steel with which he had been experimenting; the percentage of carbon being known, it was possible to form and have a very good idea of the tenacity. Mr. Sauveur spoke of the value of the pyrometer. He could not too strongly endorse the author's conclusions in that respect; but, as Mr. Ridsdale had mentioned in reply to the discussion on his own paper, it would be of great service if a pyrometer of a little more practical nature could be devised. There was no doubt that for scientific purposes the instrument which the President had brought to such an admirable state of perfection was exceedingly useful; but when they came to apply it practically to every-day work, it was found to be difficult to manipulate—some of the causes being those humorously referred to by his friend Mr. Stead. Regarding Dr. Howe's remarks on the paper, he thought an important point had been brought out there with reference to the crystallisation produced during the heating stage of a specimen of steel. Dr. Howe was, it was true, only dealing with small specimens of steel, but he (Mr. Hadfield) thought that his conclusions would more or less apply to larger masses. He had read the paper with so much interest that it was only after much hesitation that he had decided to criticise the author in his absence; but he had always found Mr. Sauveur very broad-minded, and hoped, therefore, that that gentleman would see his way to clearly defining which type or grade of steel he had in view when drawing the conclusions in question.

Mr. F. W. Paul said the paper would require very careful study to warrant any one in criticising it. Unfortunately they did not get the papers early enough to enable members to deal with confidence with such important questions. He rather gathered, from a hurried glance at the paper, that the author treated tempering and annealing as one. He thought tempering was quite apart from annealing, because he looked upon tempering as an increase of tensile strain, irrespective of what its ductility might be, whereas annealing in the true sense he looked upon as bringing a steel to its minimum of tensile strength with a maximum of ductility. Of course, these were generalisations, and he was not in any way laying down or suggesting a well-worded definition of tempering or annealing. The author said in his "Conclusions," "Since it seems to have been conclusively shown that the smaller the grains of the metal the more ductile and tough it will be, it is evident that we should endeavour to impart such a structure to all finished pieces;" but, later on, he showed that by heating up to *V*, although the grains might be broken up, yet this was not to such an extent as it would be if it were heated up to *W*; "and consequently the metal, after being re-heated to *V*, does not possess all the ductility that could be its own." He was not quite sure that that was true of all grades of steel, as Mr. Hadfield had pointed out. Probably the variance of observation and opinions was due to that. He had found that taking steel of about 0·5 carbon, such a steel would possess the finest qualities that steel possibly could without re-heating up to *W*—in fact, not up even to the temperature *V*. Such a steel by heat treatment would give, say, 60 tons to the square inch, and would have such ductility that a $\frac{3}{4}$-inch round bar would bend double. Such facts, he thought, were worthy of note, and therefore one should not accept all these observations as applicable to all steels, and as a sure guide to attain excellence in steel by heat treatment. The paper itself reminded them of the researches of Mr. Brinell in this matter. It was significant to note that the Institute had not in any way afforded them an opportunity of obtaining Mr. Brinell's valuable paper. He strongly appealed to the Council to consider whether they could not publish a translation in pamphlet form, and not only circulate it amongst the members, but print it in such numbers that it could be circulated in every smith's shop throughout Great Britain. Then with regard to the very interesting information conveyed in Appendix 3, that the size of the grains of steel hardened above *W* remained unaltered when heated up to *V*, he had pleasure in saying that in his opinion this original information, apart from the otherwise general excellence of the paper, was well worthy of the Institute. In his experience he had found that in heating even below *V* such steel as he had described of about ·50 carbon, that the fracture was changed to a close, dull, fibrous nature when examined by the eye, but it had never for a moment occurred to him that this change would not have been equally borne out when examined microscopically.

He should have hesitated even to have suggested that further investigation was necessary; but as Mr. Sauveur had expressed the hope that others would investigate the subject, he had during the visit of the Institute to the Horwich Works the day before, availed himself of the kindness of Mr. Aspinall by subjecting a few pieces of steel to heat treatment there, with the view of confirmation on this point, and he would ask Mr. Stead if he would kindly undertake to examine these pieces microscopically, and if so, he felt sure not only would the Institute feel grateful, but it would also be appreciated by Mr. Sauveur as lending additional confirmation to his conclusions on this most interesting point.

The PRESIDENT explained that the papers were distributed a week before the meeting to members writing for copies, and that there were objections to sending them out earlier. Authors, for instance, said that if papers were sent out a long time in advance, experiments would be made with a view to refute their results. There might not be much in that, and it might not very often happen, but it was an objection from the author's point of view. With regard to Brinell's paper, that had occupied the attention of the members of the Council. He quite agreed with Mr. Paul that it was extremely desirable that there should be some reprint of Mr. Brinell's classic paper, which had been, he believed, translated into English; but upon this point the Secretary's memory was more trustworthy than his own, and he would therefore ask Mr. Brough to make a statement on the subject.

Mr. BENNETT H. BROUGH, the Secretary, said the Council had considered the question of supplementing the abstract published in the *Journal* * by republishing Mr. Brinell's paper in full, and had passed a resolution that it would be desirable to do so. But before it was reprinted, he had been instructed to apply to Mr. Brinell for his permission. He waited upon Mr. Brinell in Stockholm, and told him the wish of the Council. Mr. Brinell said that he was extremely flattered by it, and appreciated it very highly; but as his paper had been written many years ago, and great progress had been made since that date, he did not see his way to sanction the reprinting of it. He said he would rather rewrite the paper, and bring it up to date in the light of the knowledge that had accumulated since its original publication, and present it in that form to the Institute. The paper had not yet been received. He was in correspondence with Mr. Brinell, who was a very energetic member of the Institute. Unfortunately, he was a very busy man, being at the head of a large and important works, and therefore was without that time for literary labours which one wished that he had. There was already a full English translation of the paper, which was published at the expense of the Ordnance Department of the United States: a copy of that was in the Library of the Institute.

The PRESIDENT said that the members of the Institute would therefore see that the matter was far from having been neglected by the Council, who had the importance of Mr. Brinell's work fully before their minds.

Mr. E. F. LANGE said the paper had a particular interest for all practical steelmakers and workers. The Brinell chart, to which Mr. Sauveur referred, and which showed in diagram form the changes of structure in steel due to heat treatment, might be considered as a splendid illustration of theory applied to practice. As far as his own observations went in respect to the annealing of steel castings, they were in complete agreement with the conclusions drawn by the author. He found that for effective annealing the castings must first be quickly brought to the temperature *W*, then cooled quickly to *V*, and then, after prolonged maintenance at this temperature, to be cooled very slowly down from that point. His attention was first drawn to this by observing in a big annealing furnace, where, owing to circumstances of a temporary character, there was a considerable range of temperature, that test-pieces from the same kind of castings, cast at the same time and from the same steel, gave very different results according to the temperature of that part of the furnace where they had lain. No one who had read Mr. Sauveur's paper would fail to understand why important forgings such as locomotive axles should be carefully annealed before use. There was a question he should like to put before Mr. Sauveur, and that was, How far annealing could be relied upon to restore to a safe structure a steel bar which had developed a large crystalline grain through fatigue? The explanation by Mr. Sauveur of the apparent exception to Brinell's rule in the case of a piece of iron or very soft steel becoming coarsely crystalline when subjected to prolonged heating at a temperature between 600° and 750°, that is, below *W*, was most valuable. This point suggested to his mind that although the softer the steel the better it case-hardened, yet for important forgings where there was much case-hardening, such as in the motion work of locomotives, the steel should not be too low in carbon in order that the metal might have sufficient pearlite in its structure. The valuable remarks made by Mr. Sauveur with regard to the tendency of steels containing very large proportions of ferrite to coarse crystallisation seemed to lead to the very many discussions which had appeared in print on acid versus basic steel for structural purposes. It would almost seem as though those discussions really led to a consideration of a minimum carbon content for steels according to their intended use, as a sufficient amount of pearlite structure should always be aimed at on account of the tendency of ferrite to coarse crystallisation.

---

* 1886, p. 365.

## *CORRESPONDENCE.*

Professor HENRY M. HOWE, of New York City, who had read Mr. A. Sauveur's paper in manuscript, sent the following contribution to the discussion:—

The question, "Can the coarsening of the grain, structure, or crystallisation of iron occur during rise of temperature (*i.e.* during heating), or can it occur only during fall of temperature (*i.e.* during cooling)?" can be approached either by reasoning from analogy or by direct observation.

From the analogy of certain aqueous solutions it has been reasoned that this coarsening cannot occur during heating, but only during cooling. Without saying that this reasoning is untenable, I will merely say that it has not so far been presented in a way which seems to me cogent.

From aqueous solutions in general crystallisation occurs only during cooling, because crystallisation from them implies solidification, and solidification can occur only during cooling. Reasoning by analogy from this to the case of iron must be very cautious for two very evident reasons.

First, hot iron is not an aqueous, not even a liquid solution, but a solid solution. That which prevents crystallisation in aqueous solutions during heating, viz., that they are not solid and hence cannot crystallise, does not apply here at all, for the hot iron is already solid.

Second, the coarsening of the structure of hot iron is not the setting in of beginning of crystallisation, not the passage from a non-crystalline to a crystalline state, but merely the passage from one state of crystallisation to another. We refine the structure by heating to $Ar_1$; it is then fine crystalline. If on farther heating, say to 1400° C., the structure coarsens, that does not imply that crystallisation sets in during rise of temperature, or that the iron has passed from a non-crystalline to a crystalline state, but that its crystallisation has simply changed. Now the premise that crystallisation cannot (as in an aqueous solution) *begin, set in, originate,* during rise of temperature, does not imply that if (as in hot iron) it already exists, it cannot *change* during rise of temperature.

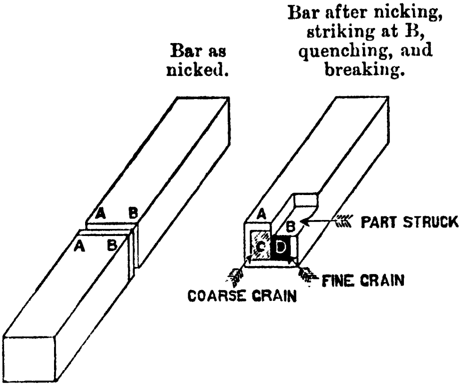
I frame this objection to the reasoning from analogy, with the wish to show wherein this reasoning seems to lack cogency, so as to offer an opportunity to supply this lack.

Turning now to direct observation, I heated a bar of steel very rapidly to a bright white heat. I am confident that during this heating the temperature was at all times rising. I quenched it in cold water very quickly; I found the grain excessively coarse. You tell me that this coarsening of grain did not occur during my rise of temperature, but during the two or three seconds which elapsed between the instant when my bar left the furnace and the instant when it had become too cold to change farther. My answer to this is twofold.

First, if your contention is true, certainly the inside of the bar, which must have cooled much more slowly than the outside, ought to be correspondingly coarser than the outside. In the experiments which I have made, I did not with the eye find this difference. But further trials of this are needed.

Second, assuming that my observations were sufficient, the only escape from the inference that the coarsening occurred during rise of temperature would be, that it occurs so extremely fast during fall of temperature as to complete itself even in the very rapid cooling of the outside of the bar. To say this, however, deprives your contention of industrial importance. For if the coarsening during fall of temperature is so extremely rapid that it can complete itself and reach the great coarseness corresponding to a bright whiteness in the very brief time occupied by the cooling of the outside of a bar $\frac{1}{4}$-inch thick, the effect is the same for all industrial purposes as if the coarsening had occurred during the rise of temperature.

The following experiment further indicated that coarsening occurs during rise of temperature. A steel bar was nicked across its middle at AB, as here sketched, was heated to bright whiteness, was struck violently at B on one half of the nick, and was immediately quenched. When now broken at the nick, the part C not struck was very coarsely crystalline, but the part D, which had been struck, was finely crystalline. This at least strongly suggests that the coarsening had occurred during heating; that the blow at AB had broken up the coarse grain on that side of the bar, and that this coarse grain had not had time to re-form during the cooling. This certainly goes to show that the growth during cooling is not so extraordinarily rapid, and hence to show that the coarsening of my first bar, simply heated white hot and immediately quenched, could not have had time to occur during that brief cooling, and hence must have occurred during heating. The experiment, however, is not conclusive, but I have started others which I hope will be. I should have delayed writing on this subject had not Mr. Sauveur's remarks offered an opportunity which it seemed best to accept.


Bar as nicked.

Bar after nicking, striking at B, quenching, and breaking.

Mr. F. Osmond hoped that the author would add to his interesting paper a sequel, in which the general aspect of the whole question, the relation between the structure of steel and its thermal and mechanical treatment, would be dealt with. There was no doubt that the author was fully qualified for that task. In the present paper it was hypothetically admitted that the three critical points were combined in the single one *V*, *W*, but the author, who had himself made most important investigations on the variations of the micro-structure in relation to the temperature of hardening, knew as well as any one that those conditions were only exactly conformed to by the eutectic steels, and that they were deviated from as the carbon contents became lower. For the moment the author appeared to have neglected the more complex part of his subject, so as to induce others, less familiar with the matter to follow. But he must not abandon them by the way; he must aid them by the loan of all his knowledge and his powers of lucid explanation.

Taking the paper as it stood, with its limited application to carbon steels containing, say, not less than 0·60 per cent. of carbon, he (Mr. Osmond) had but few observations to make, and they related exclusively to points which the author considered as open for discussion.

1. The first of these was the development of the grain above *W*. He himself had examined this question,* and had arrived at the same conclusion as Professor Howe, viz., that the crystallisation took place during heating as well as during cooling, and depended principally on the maximum temperature. Although this conclusion, arrived at some considerable time ago, was based on experiments which appeared to be far from conclusive at the present time, yet it seemed to be confirmed rather than upset by later investigations. If two fragments of steel, containing 0·45 per cent. of carbon, were heated to 1200° C., and one was quenched and the other cooled slowly, the martensite grains in the hardened piece were not very much smaller than the pearlite grains in the annealed sample. That agreed with Brinell's observations. As Professor Howe had remarked, solid solutions were not exactly assimilable to liquid solutions. For a crystal to grow, it must find free solid crystalline molecules within reach. In a liquid solution this condition could only obtain during cooling, but in a solid solution, as now defined, the solid molecules were always present. In order that they might abandon one crystal to the profit of its neighbour, it would suffice if they were diverted to such an extent, either by heat alone, or by the interposition of foreign molecules, as to take a new position under the inducement of the largest of the adjacent agglomerations.

2. The author appeared to have found some difficulty in defining and differentiating the terms annealing and tempering. It would seem as if a distinction would be clearly and logically drawn on the same principles as he (Mr. Sauveur) invoked in distinguishing between hot and cold working. In other words, annealing would be a heating above *W* followed by slow cooling

---

* "*Etudes Metallurgique*," *Annales des Mines*, Series 8, vol. xiv. pp. 59-80.

whilst tempering would be a heating to a point below *W* with subsequent slow or rapid cooling, and would have no useful effect except after quenching or cold working. This was the definition given by Sir W. C. Roberts-Austen. It had been accepted by the French Commission on methods of testing, and did not appear to be subject to objection. It would be of advantage if its use were made general.

3. When previously hardened steel was tempered at a point below *W*, the hardening carbon was known to revert to carbide carbon. The change, as the author justly remarked, proceeded *in situ*, but the reconstituted carbon only remained in that condition up to a certain temperature. If *W* were approached, without reaching that point, however, this carbide had a tendency to become isolated, and to separate the ferrite in small grains. At least this was the result of his own micrographic investigations,* and they appeared to confirm the suggestions of Mr. Brinell, which were dealt with in the third appendix to the paper.

Mr. J. E. STEAD wrote to state that the steels experimented with by Mr. Paul and himself at the Horwich works, to ascertain whether or not Mr. Sauveur's statement, "that the size of the grains of steel which had been hardened above W remained unaltered when heated up to V," had been examined microscopically at Middlesbrough. The results confirmed Mr. Sauveur's statement. On examining the fractures magnified, it would appear that on breaking the re-heated steels the grains were more or less drawn out, and the finer structure thus obtained. A similar kind of structure was produced by breaking tough coarse-grained soft steel.

Mr. ALBERT SAUVEUR sent the following reply to the discussion on his paper:—I am gratified at the amount of discussion which my paper called forth, and I hope that it will be further criticised, and that it will induce others to verify by actual experiments the accuracy of my statements.

Following up Professor Howe's reasoning, it is not easy to see how a solid may pass from a crystalline condition to another crystalline condition without passing by an intermediate amorphous condition; it is not easy to see how a coarse crystallisation may quite abruptly be replaced by a very fine one without the metal first assuming an amorphous state.

---

* *Bulletin de la Société d'Encouragement*, 1895, p. 507.

The contention, moreover, that upon reaching *W* the steel loses a pre-existing coarse crystallisation to assume a fine crystalline condition might be disputed, for I see no conclusive evidence that the steel in passing through *W* does not assume a true amorphous condition. The examination of the microstructure of some samples of steel heated to *W* as exactly as possible and slowly cooled, leaves me in doubt as to the character of their structure. In other words, I do not know whether to call it amorphous or finely crystalline.

Professor Howe's experiments to settle the point at issue are interesting and valuable, and, of course, at first sight, support his contentions, but, as he himself says, they are not conclusive, and further inquiry is needed before it can be put down as an acquired fact that steel does crystallise while its temperature is rising.

I cannot quite follow Mr. Hadfield's charge of want of clearness in some portions of the paper. Mr. Hadfield asks what I mean by the expression "a piece of steel." Now that expression seems very clear to me. If I did not specify whether I meant a high carbon steel or a low carbon steel, or any other steel, it is because I did not see any necessity for doing so. My propositions, as far as my experience goes, apply to all grades of carbon steel, with the exceptions to which I call attention in footnotes and appendixes.

If I say that man is mortal, there is nothing obscure in that sentence, and I need not specify, I think, whether the man is small or tall, rich or poor.

Of course, I do not mean that in order to secure the finest possible structure it is sufficient to heat the steel to a certain temperature, *W*, which is the same whatever the steel. No one who will read my paper with care will gather from it such an impression, for I very clearly state that the *W* temperature varies with the composition of the steel, and that it should be determined in every case; that is why I recommend the use of pyrometers in the heat treatment of steel. Mr. Hadfield states that there is no doubt that the point *W* is not the same in hard as in soft steel. This is undoubtedly true, and I have taken pains to say so in my paper.

It was my endeavour in the present contribution to formulate a set of propositions that would apply to all grades of steel, and now I am asked to give in every case the exact chemical composition and the exact previous treatment of the sample of steel upon which each of my statements is based. This would be missing my purpose utterly. These propositions are not based upon any one sample in particular, but are the results of an inquiry into the heat treatment of steel continued during many years, and embracing all grades of carbon steel, and they are offered as a help in the treatment of any carbon steel, always keeping in mind the exceptions which I have recorded.

While it would be very gratifying to see the accuracy of my statements stand the test of the most searching light, my greatest desire is to witness the progress of our knowledge of the treatment of steel, and to be fortunate enough to contribute to it, if only in a trifling manner; and if in any particular case my propositions are found inapplicable, I hope that the fact will promptly be brought to light, so that they may be corrected accordingly and their usefulness increased.

I note Mr. Paul's remarks concerning a 0·40 per cent. carbon steel, which, after being heated to *V*, or even below *V*, possessed all the toughness and ductility which it was capable to assume. This is opposed to the result of my observations. Of course *V* and *W* lie so near each other that, unless a pyrometer was used to record these critical points, it would not be safe to assert that the piece had not reached the temperature *W*. Only extremely careful treatment, with the assistance of a trustworthy pyrometer which will locate the critical points, will warrant safe conclusions upon this point. Judging of the temperature by the eye is here altogether unreliable. It is interesting to note that Mr. Lange also had reached the conclusion that in order to properly anneal steel castings they should be heated to *W*, then cooled to *V*, and maintained at that temperature a certain length of time.

The question was asked by Mr. Lange how far annealing could be relied upon to restore to a safe structure a steel bar which had developed a coarse crystallisation through fatigue. It is a point which I never had occasion to investigate, and upon which I hesitate to give an opinion, the more so that our knowledge of the structural changes brought about by fatigue is of such a limited and unsatisfactory character.

The PRESIDENT proposed a hearty vote of thanks to Mr. Sauveur for his paper. Professor Campbell's paper was taken as read, and the thanks of the Institute were accorded to him.

# THE CONSTITUTION OF STEEL.

By Professor E. D. CAMPBELL, Ann Arbor, Michigan.

In the interesting paper read at the last meeting* by Professor Arnold and Mr. M'William, the authors say, "Professor Campbell seems in error on one important point, namely, with reference to the alleged non-diffusive power of pure sulphide of iron." I feel, however, that if the different conditions under which the authors' and my own experiments were carried on are considered, it will be seen that there is, after all, nothing in the experiments described that will contradict the statements in my own paper. Although my own experiments were originally undertaken to prove that an undoubted chemical compound can diffuse through steel, I have, myself, never felt satisfied that the passage of sulphide of iron through steel could, in strict sense, be regarded as true diffusion; it has always seemed to me to be a phenomenon rather of filtration through a porous body, than true diffusion. To me the phenomenon of true diffusion in solids involves, first, solid solution of the diffusiate in the entire mass, and intermolecular movement of the diffusiate, whereas filtration involves the passage of the filtrate in liquid form through the capillary spaces between the solid particles of metal, these particles being of very appreciable size. Professor Arnold has himself very ably shown microscopically that sulphide of iron occupies the minute interstitial spaces between the relatively large particles of iron, rather than occurs in solid solution throughout the mass of the metal, and my own experiments have shown, by the tendency of the sulphides to accumulate near the lower part of the bar, that the diffusiate is in liquid form, during its passage through the steel. It would seem, then, to me that, if what I have termed the diffusion of sulphides through steel is, strictly speaking, a phenomenon of capillarity rather than true diffusion, we might justly expect the diffusive power of different substances to be influenced by the same conditions that would affect ordinary filtrations. It is well known that if the cohesion of a liquid is greater than its adhesion to the walls of a porous vessel containing it, the liquid will not enter the pores of the container and filter through it; on the other hand, a liquid may be drawn through a porous body by a vacuum when it would not enter the pores under atmospheric pressure. This is illustrated by the familiar example of the filtration of water and of mercury through a longitudinal block of wood; the water will readily penetrate and filter through, even under ordinary pressure; the mercury will remain on the upper surface of the wood so long as the pressure above and below are the same, but will be forced through if a vacuum is produced beneath the block. To me, the differences in result on oxysulphide and pure sulphide of iron are due to just this same difference in conditions of experimentation. In several of the experiments made in this laboratory, the plugs used for closing the hole during the diffusions were raised out of position, thus giving evidence of more or less internal pressure, although this pressure does not seem to have been very great. In my own experiments, therefore, only those sulphides whose cohesion was less than the adhesion to the walls of the capillary spaces in the metal, would diffuse or filter through the iron and be absorbed by the porous scale on the exterior, or the asbestos on which the bar rested. The cohesion of pure sulphide of iron seemed to be greater than the capillary attraction of the pores of the steel, and in consequence this substance remained practically unchanged in the bar, when the outside of the bar was at atmospheric pressure, although Professor Arnold and Mr. M'William have shown that the pure sulphide will be drawn through the pores of the steel if the bar is *in vacuo* during the experiment. I feel that the experiment serves rather to confirm than to contradict the conclusions drawn from my original experiments, namely, that steel must be regarded as a porous body, through the pores of which a liquid may be made to filter, provided the cohesion of the liquid is not too great. Oxysulphide of iron is such a mobile liquid, that is, has such low cohesion, that it will enter the pores of the steel and filter through, assisted only by capillary attraction. Professor Arnold has now demonstrated that, although the cohesion of pure sulphide of iron is greater than the capillary attraction of the steel, nevertheless this cohesion may be overcome, and the liquid sulphide be drawn through the pores of the steel, provided the external pressure is sufficiently reduced.

---

* *Journal of the Iron and Steel Institute*, 1899, No. I. p. 85.

The results obtained by Professor Arnold in his experiments on the diffusion of phosphides seem to me to be of much more significance than those obtained with sulphides. In the case of the phosphide, judging from his microscopical examinations, the phosphorus compound, whatever it may be, seems to be in true solid solution, evenly distributed throughout the entire mass, and, consequently, to have diffused in the strict sense of the word, from the inner core into the surrounding jacket. The sulphide, on the other hand, has been drawn by capillary action for a short distance into the interstitial spaces of the steel. This interstitial penetration will not extend far into the jacket, since the penetrating sulphide, instead of existing pure and in relatively unlimited amount as in the experiments conducted here, already occupies the interstitial spaces of the core, so that there would be little tendency for it to change its location, the capillary attraction of the containing interstitial spaces being as great as that of the surrounding jacket.

Now that Professor Arnold seems to have demonstrated by his experiments with phosphorus that diffusion in the strict sense of an undoubted chemical compound can take place in iron, I feel as he does that there is no experimental proof that the diffusing carbon in iron is necessarily in the elemental form. Although in the experiments of Mr. G. P. Royston * it would seem at first glance that the diffusing carbon must be in the elemental form, a consideration of the laws of solution will show that this assumption need not necessarily be made. If we regard the carbon in steel at, say, 850° C., to be present in the form of dissolved carbides or ferro-carbons, and that these dissolved ferro-carbons are more or less ionised, it would seem to me much easier to conceive how carbon ions might migrate from high-carbon into low-carbon steel without losing their chemical relation to iron ions, than it would be for me to understand how we could obtain the same products of solution from a definite chemical compound of iron and carbon that we would obtain from a mere mixture or solution of free uncombined carbon in

---

* *Journal of the Iron and Steel Institute*, 1897, No. I. p. 166 *et seq.*

iron. Before the carbon solution theory can be considered as definitely proved, it will be necessary for the "carbonists" to bring forward some satisfactory explanation of the behaviour of solvents toward annealed and hardened steel. Although our experiments are far from complete as yet, and we hope to continue the investigations along the present lines of research, the results so far obtained may serve to throw a little light upon the vexed question of the constitution of steel.

In my discussion of Mr. A. Sauveur's paper on "The Microstructure of Steel and the Current Theories of Hardening,"* I stated the firm belief which I held at that time, and which I still hold, that we are not only justified in depending upon the products of solution of steel for deducing the constitution of the iron and carbon compounds, but we must turn to these products for the desired information in regard to these bodies. In studying the constitution of practically all chemical bodies, whether organic or inorganic, it is assumed that if two compounds under the action of the same solvent and same conditions of solution yield the same or similar products, the bodies dissolved have the same or similar constitution. It is upon this assumption that our present investigations were commenced some eight years ago, and although our results are far from complete, they point towards some rather interesting conclusions, which we hope to be able to verify by means of further work along the lines indicated by the results so far obtained.

As early as 1864 Hahn† obtained from different cast irons a variety of hydro-carbons, a part being gases, belonging to the olefine series (*i.e.* having the general formula $C_nH_{2n}$); a part gases of the paraffin series (general formula $C_nH_{2n+2}$); and a part unidentified liquid hydro-carbons. Later, in 1877, Cloez‡ dissolved a large sample of manganiferous white iron, and recovered part of the carbon by absorbing the gaseous olefines in bromine, thus converting them to the di-brom derivatives, this absorption taking place according to the equation: $C_nH_{2n} + Br_2 = C_nH_{2n}Br_2$. In addition to the carbon obtained in the above manner, Cloez obtained also a portion of his carbon as low-boiling liquid paraffins, especially $C_{12}H_{26}$, together with some unidentified liquid hydro-carbons. Both Hahn and Cloez proved qualitatively that the olefines—ethylene ($C_2H_4$), propylene ($C_3H_6$), butylene ($C_4H_8$), and pentylene ($C_5H_{10}$)—and di-butylene ($C_8H_{14}$) were present in the gases; and Cloez identified the paraffins from decane ($C_{10}H_{22}$) to hexa-decane ($C_{16}H_{34}$). Both mention that duo-decane ($C_{12}H_{26}$) was the predominant member of the oily paraffins. The work of neither of these chemists was strictly quantitative; and neither attempted to account for the total amount of carbon, or to deduce from their results any generalisations which might lead to a theory concerning the relation of carbon to iron.

---

* *Transactions of the American Institute of Mining Engineers*, vol. xxvii. p. 869 *et seq.*

† Liebig's "Chemical Analysis," vol. cxxix. p. 57.

‡ *Comptes Rendus*, vol. lxxxv. pp. x, 3.

The general method which we have employed for studying the products of steel has been to dissolve the steel in hydrochloric acid, pass the gas evolved through bromine in order to convert unsaturated hydro-carbons of the general formula $C_nH_{2n}$ into their di-brom derivatives $C_nH_{2n}Br_2$; the gas passing through the bromine being measured, and the carbon existing as gaseous paraffins being determined by explosion and absorption of the carbon dioxide produced. The di-brom derivatives, after proper purification, drying, and weighing, are analysed and fractionally distilled for the purpose of qualitatively identifying the various constituents; although the fractional distillation of the di-brom derivatives has shown the presence of ethylene, propylene, butylene, pentylene, and hexylene di-bromides, and dibutylene tetra-bromide, later investigations have convinced us that this last product is the result of the polymerisation under the influence of heat during distillation of butylene di-bromide, and is not present, to any considerable extent at least, in the original derivatives. Although the di-brom derivatives from ethylene dibromide ($C_2H_4Br_2$) to hexylene dibromide ($C_6H_{12}Br_2$) have been detected qualitatively, the separation of the various derivatives by fractional distillation *in vacuo* is not sufficiently sharp to give accurate quantitative results in regard to the amount of each constituent present. We therefore have, for the present at least, contented ourselves with calculating from the per cent. of bromine in the di-brom derivatives the average number of carbon atoms in the molecule.

The results of the examination of a few samples of steel by the above method are shown in the following table:—

| Name. | Heat Treatment. | Per Cent. of Carbon of Steel. | Per Cent. of Carbon as Derivatives. | Per Cent. of Carbon as Gaseous Paraffins. | Per Cent. of Carbon Unaccounted for. | Per Cent. of Bromine in Derivatives. | Calculated Carbon Atoms in Carbon Molecule of Derivatives. |
|---|---|---|---|---|---|---|---|
| F | Annealed | 0·55 | 37·1 | 33·6 | 29·3 | 72·56 | 4·32 |
| F | Hardened and Tempered | 0·55 | 25·0 | ... | ... | 75·65 | 3·67 |
| C | Annealed | 1·14 | 43·4 | 37·9 | 18·7 | 73·85 | 4·05 |
| C | Hardened | 1·14 | 29·0 | 48·6 | 22·4 | 77·61 | 3·31 |
| D | Annealed | 1·28 | 31·0 | 44·3 | 24·7 | 77·80 | 3·26 |
|  | Pure Carbide from D annealed | 6·64 | 35·3 | 25·2 | 39·5 | ... | 4·41 |

The number of carbon atoms in the carbon molecule of the derivatives from the pure carbide, given in the above table, was obtained from the analysis of the gas by dividing the volume of carbon dioxide, produced from the explosion of the olefines, by the volume of the olefines exploded.

We know from a study of the above table that—

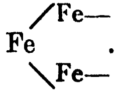
First, the average number of carbon atoms in the molecule derived from annealed steel decreases as the per cent. of carbon increases.

Second, that in annealed steel the proportion of carbon escaping as gaseous paraffins, probably as methane ($CH_4$) or ethane ($C_2H_6$), increases as the per cent. of carbon increases.

Third, that with the same steel, the effect of hardening seems to be to lower the number of carbon atoms in the molecule of derivatives, and to increase the proportion of carbon escaping as gaseous paraffins.

Fourth, from the per cent. of carbon in the above steels, it will be noted, that "F annealed" must consist of pearlite with ferrite, whereas "C annealed," and "D annealed," consist of pearlite with increasing amount of cementite. The number of carbon atoms in the molecule of derivatives from "F annealed," and "pure carbide" isolated from the pearlite in "D annealed," is nearly the same, 4·32 as compared with 4·41. Since the number of carbon atoms from "D annealed" is so much lower than from the pure carbide, the inference would be that cementite must yield derivatives of small numbers of carbon atoms in order to bring the average down to 3·26.

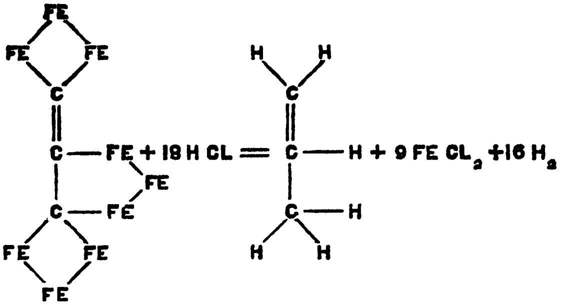
The results obtained from the examination of the steels, as shown in the preceding table, would indicate almost positively that there are several carbides existing in steel, and that these carbides have different molecular weights. In all of the theories of the constitution of steel at present held, the formula $CFe_3$ is assigned to the carbide existing in annealed metal; this formula is merely an empirical one, representing only the results of ultimate analysis, without attempting to account in any way for molecular constitution; the same criticism would hold true of the formula $CFe_{24}$, which represents the ultimate composition of martensite. Any theory which assigns so simple a formula as $CFe_3$ and $CFe_{24}$ to the carbides of annealed and hardened steel, without taking into consideration the molecular weight of the carbides, simply because the carbides contain respectively 6·67 and 0·89 per cent. of carbon, is as unsatisfactory as it would be to say that all hydro-carbons of the olefines series have the formula $CH_2$, because they all contain 85·71 per cent. carbon.

In view of the fact indicated by our work on steel, I would venture to repeat again the hypothesis which I suggested in February 1897, before the American Institute of Mining Engineers. This hypothesis which I would offer, makes the fundamental assumption that carbon forms with iron a series of compounds which might properly be termed "ferro-carbons," on account of their similarity in structure to hydro-carbons. This series of ferro-carbons has the empirical formula $(CFe_3)_n$; or, as I prefer $C_nFe_{3n}$, this series of ferro-carbons are to be considered as being derived from the hydro-carbons of the olefine series with the general formula $C_nH_{2n}$, by the replacement of the $H_2$ by the bivalent group  $\mathrm{Fe}\begin{matrix}/\mathrm{Fe}-\\ \backslash\mathrm{Fe}-\end{matrix}$. These ferro-carbons, dissolved in hydrochloric acid, yield as their primary products of solution the corresponding olefines and hydrogen. Thus, the first member of the ferro-carbon series, $CFe_3$, should yield as its products of solution, methylene, $CH_2$, and hydrogen; the second member,

$C_2Fe_6$, should yield ethylene, $C_2H_4$, and hydrogen; the third, $C_3Fe_9$, propylene, $C_3H_6$, and hydrogen, &c. As a matter of experience, however, we do not find the products of solution to be as simple as would be indicated by the above description, on account of two well-known facts. First, because the olefines have a tendency to combine with nascent hydrogen to form the corresponding paraffin, according to the equation: $C_nH_{2n} + H_2 = C_nH_{2n} + {}_2$. This would readily account for so large a proportion of the carbon being found as methane ($CH_4$), with probably some ethane ($C_2H_6$), since methylene ($CH_2$) has as yet never been isolated, owing to its extreme chemical activity. The second factor which would tend to complicate the products of solution is the strong tendency of the higher olefines to polymerise under the action of acids; this tendency is quite marked in the case of propylene, and is very strong in the case of butylene and higher members.

The carbon unaccounted for in the above analyses remains as liquid hydro-carbon of high boiling-point, which does not pass over with the steam or hydrogen when the steel is dissolved. Whether these high-boiling hydro-carbons are primary products of solution, or result from polymerisation and hydrogenation of lower members of the series, we are not at present able to state.

The solution of the ferro-carbons would be shown in the following graphic equation:—



In annealed steel containing less than 0·89 per cent. carbon, and consisting therefore of pearlite with more or less ferrite, we would find the eutectic pearlite consists of alternate laminæ of ferro-carbon, $C_nFe_{3n}$, and laminæ of iron, $Fe_{21n}$. This $Fe_{21n}$ may be regarded as iron of crystallisation, the ferro-carbons occurring in pearlite having a higher molecular weight than those occurring as cementite.

When annealed steel is heated above $Ar_1$, the ferro-carbons $C_nFe_{3n}$ dissolve in the iron of crystallisation, $Fe_{21n}$, forming what Professor Arnold has happily termed the "cryo-carbide" martensite, $C_nFe_{3n} \cdot Fe_{21n}$. Although this "cryo-carbide" has the same empirical formula as Professor Arnold's sub-carbide $CFe_{24}$, the formula $C_nFe_{3n} \cdot Fe_{21n}$ seems to be more in accord with our conceptions of chemical constitution and of the constitution of cryohydrates. The formula $C_nFe_{3n} \cdot Fe_{21n}$ accounts for the molecular weight of the existing ferro-carbons, and, although there is a definite amount ($Fe_{21n}$) of iron associated with the $C_nFe_{3n}$, just as there is a definite amount of water associated with a fixed amount of sodium chloride in the cryo-hydrate, all the 24n atoms of iron do not bear the same chemical relation to the *n* atoms of carbon, but 3n atoms of iron are combined with the carbon to form the ferro-carbon, the remaining 21n atoms of iron bearing the same relation to the ferro-carbon molecules that the water in the cryo-hydrate bears to the molecule of sodium chloride. When the ferro-carbons of high molecular weight dissolve in their iron of crystallisation, they probably begin to split up to a greater or less extent, yielding lower members of the series, this dissociation increasing with rise of temperature. The exact extent of this dissociation, under the influence of varying temperature, is still being investigated in this laboratory.

The points $Ar_2$ and $Ar_3$ may both indicate points of increased dissociation of the ferro-carbons, or one of these may denote an allotropic change in the iron. The dissociation of the ferro-carbons goes on with increased temperature, as is indicated by calculations of Baron H. von Jüptner,* who shows, from the depression of the melting-point of steel, that at the melting-point the carbon molecule does not contain more than two atoms of carbon.

When low-carbon steel is slowly cooled from very high temperatures, the dissolved ferro-carbons begin to polymerise and segregate with the iron constituting the cryo-carbide, until at $Ar_2$ the pure cryo-carbide martensite has separated completely from the surrounding ferrite. As the temperature falls to $Ar_1$, the ferro-carbons crystallise out with their iron of crystallisation, constituting the eutectic pearlite.

---

* *Journal of the Iron and Steel Institute*, 1898, No. II., p. 247.

Another argument in favour of the probable existence of a series of ferro-carbons is found in the behaviour of steel toward nitric acid, in the well-known colorimetric method for the determination of carbon. It is well recognised among steel analysts that, in order to obtain reliable results, it is necessary that the unknown sample and the standard with which it is compared should not only have approximately the same carbon content, but should have been subjected to the same heat treatment. If there were but one carbide of iron, it is hard to understand why the depth of colour obtained by dissolving in nitric acid should not be directly proportional to the amount of carbon in every case, so that low-carbon steels could be accurately compared with high-carbon standards. If, however, we assume the existence of several ferro-carbons, we can very readily see why it is necessary, in order that the nitro derivatives should be the same, that the standard and the unknown should have approximately the same per cent. of carbon and the same heat treatment, since large variations in the per cent. of carbon and varying heat treatments alter the members of the ferro-carbon series existing in steels.

Again, because the ultimate composition of the carbide in pearlite is probably the same as that constituting cementite, the statement is usually made that pearlite consists of alternate laminæ of cementite and ferrite. It is hard to conceive how this can be the case if there were but one carbide of iron in annealed steel, and this had the formula $CFe_3$. We might, if this were true, justly expect that this carbide and the crystallised iron associated with it should have the same solubility as the two constituents when separate. Cementite remains bright under the action of iodine and of nitric acid, as does also ferrite, yet pearlite, which is said to consist of alternate laminæ of these two constituents, neither of which is acted upon by the reagents in question, is readily coloured by both. If, however, we conceive that the carbides in pearlite and in cementite are not the same but different members of a ferro-carbon series, we can then readily understand the difference in solubility of the two substances.

Hydrogen must be regarded as very closely related to the metals, and it is hard to understand how there is any inherent reason why the formation of complex molecules of carbon should be confined to compounds of carbon with hydrogen and the non-metallic elements like oxygen, nitrogen, &c.; why hydrogen in various hydro-carbons should not be capable of being replaced completely by metals, forming what might properly be called metallo-carbons. If we succeed in establishing the probable existence of ferro-carbons, it is proposed to take up the study of some of the other carbides, in order to determine whether or not other series exist.

## *CORRESPONDENCE.*

Mr. F. OSMOND thought that he was in agreement with the author in all his essential conclusions on the probable existence of several ferro-carbons of the same empirical formula, $Fe_3C$, and he only wished to offer some remarks on certain of the accessory points.

1. The author considered the iron of the pearlite as iron of crystallisation, but it was questionable if this comparison was completely justifiable. Certainly the iron of the pearlite was similar to the ice-crystals in a solidified cryohydrate, but in each case the two structural elements were merely in juxtaposition. The molecules of one had no relation to the molecules of the other constituent, and a mixture was precisely the contrary of a chemical compound. A formula such as $Fe_3C,Fe_{21}$ could not be given to it. Perhaps, however, the formula was only applied above the point *A*—*i.e.*, to martensite. With that interpretation the iron of the pearlite could well be considered as similar to the water of crystallisation in a salt, if it were supposed that the iron had some molecular relation to the carbide. But then, water of crystallisation formed an integral part of the molecule, and was not, like the ice, intermingled with the salt crystals in a cryohydrate. Under all aspects, the author's comparison appeared to raise difficulties.

2. In the paper it was stated that "the points $Ar_2$ and $Ar_3$ may both indicate points of increased dissociation of the ferro-carbons, or one of these may denote an allotropic change in the iron." If this quotation meant that the carbon displaced the points $Ar_2$ and $Ar_3$, and that the isomeric changes of carbide were allied to the allotropic changes of the iron, no objection could be raised; but if it were to be taken literally, it must be remarked that both the points $Ar_2$ and $Ar_3$ decidedly represented allotropic modification, for the very peremptory reason that both occurred in pure iron.

3. Eggertz's colorimetric method undoubtedly showed that the carbon in hardened steel was not in the same condition as in annealed steel, but he could not clearly discern what

deductions should be drawn as regarded the nature of the difference.

4. The manner in which the pearlite was attacked did not in itself prove that the cementite of the pearlite differed from the independent cementite. It was true that pearlite became coloured under the action of suitable reagents, while ferrite and cementite remained uncoloured under the same conditions. The colouration in question was not, however, a real colouration. It was an optical effect due to the decomposition of light by its reflection from a slightly irregular (denivelée) surface. When the elemental structure of the pearlite was sufficiently coarse, as occurred, for instance, after very slow cooling, its components, ferrite and cementite, both remained uncoloured after etching. Still it was not less unlikely that cementite of the pearlite, as Professor Campbell thought, might differ by its molecular condensation from the independent cementite; but Weyl's method of etching with hydrochloric acid at the positive pole of a cell was better adapted for supplying matter for argument on those lines.

Apart from these observations, which did not affect the real root of the matter, he had no objections to urge against the possible existence of a family of ferro-carbons. He thought, with the author, that the formation of a series of hydro-carbons during solution in acids, and the influence of hardening and annealing on the respective proportions of those bodies, were very weighty arguments in favour of the theory. To them two further points might be added.

1. In hypereutectic steels and in white pig iron it was known that part of the independent cementite existed at a temperature more or less above the point $A_{3\cdot2\cdot1}$—*i.e.*, at a temperature where magnetism had disappeared.

2. The substitution of a suitable amount of manganese for the iron in the cementite caused the magnetic properties to disappear at the ordinary temperature without altering the type of the empirical formula.

These two facts seemed to prove the existence of at least two isomers of the carbide $Fe_3C$, one of which was magnetic and the other non-magnetic. It should be remarked, however, that all these proofs which had been adduced, whether they depended on a study of the magnetic properties or on the investigation of hydro-carbons evolved during solution in acids, related only to the carbide of iron, and that most of the other metallic carbides were excluded from their application. For that reason, it was quite permissible to suppose that the polymerisation of carbide of iron could indeed be, at least in part, simply the consequence of the molecular transformation of the iron it contained.

Mr. RIDSDALE said there was just one point in Mr. Campbell's paper to which, as it was independent testimony on an interesting fact of considerable practical importance mentioned in his own paper given at the same meeting, he wished to draw attention. He referred to the fact that, whilst under certain treatment steel might behave as if perfectly sound, and *was* perfectly sound in the ordinarily accepted sense, yet other treatment could, by developing hollowness, make it appear to have been unsound, although the only unsoundness was minute blowholes or porosities common to *all* steel of *every* make, these sufficing for the purpose under such conditions. Mr. Campbell's testimony was in the passage where he spoke of "the passage of the filtrate through the capillary spaces between the solid particles of metal," and quoted Professor Arnold's mention of "interstitial spaces," and again, later in the paper, where he (Mr. Campbell) said "steel must be regarded as a porous body, through the pores of which a liquid may be made to filter." These statements, and the experiments cited, coming from such a source, were of great practical value.

## VOTES OF THANKS.

The PRESIDENT then said: I have now, gentlemen, to propose a comprehensive series of resolutions. The first is, "That the best thanks of the Iron and Steel Institute be and are hereby tendered to the Right Honourable the Lord Mayor of Manchester for his kindness in granting the use of the Town Hall of this city for the purposes of this meeting, and for his hospitable reception of the members of this Institute." All who were present last night and took part in the gracious reception by the Lord Mayor and the Lady Mayoress will, I am sure, feel that seldom, if ever, have we had a more brilliant or cordial reception than that which has been accorded to us by the Chief Magistrate of this great city and by his charming wife. The second is, "That the best thanks of the members are hereby given to the Chairman, Mr. S. R. Platt, to the Deputy-Chairman, Mr. Henry Webb, to the Honorary Secretary, Mr. Thomas Ashbury, and to the members of the Local Reception Committee, for the great cordiality of the welcome extended, and for the arrangements, ably planned and successfully carried out, for the convenience, instruction, and pleasure of the members during the present meeting." No words of mine are necessary to add to the terms of this resolution, for that the success of the meeting is due to the infinite care displayed by the gentlemen I have mentioned is evident to us all. The meeting is happily not yet at an end, and we shall, in the various excursions, still gather the fruits of the labours which have occupied them so long. I have also to add, "That the best thanks of the members are also hereby given to the Lancashire and Yorkshire Railway Company, the Great Central Railway Company, the Midland Railway Company, and the London and North-Western Railway Company for providing special free trains; further, that the best thanks of the members are hereby given to the proprietors and managers of the various works in the district for their great courtesy in receiving the members, and to the committees of the clubs of the city for the privileges accorded to the members of this Institute." Here again the advantages of the privileges we have enjoyed are so obvious, and their magnitude is so great, that I need not embroider in any way the terms of this resolution. I therefore propose the resolution in the terms that I have already read out.

Sir LOWTHIAN BELL, Past-President, had very much pleasure in seconding the resolution, moved in such fitting and appropriate terms. It was about thirty years since he had invited the attendance of three gentlemen at his house in order to consider the propriety of establishing the Iron and Steel Institute. His object at that time was to endeavour to introduce to the notice of the iron manufacturers of this country the desirability of importing the aid of science more frequently and more extensively than had been done up to that time. If any gentleman would take the trouble of comparing the amount of science introduced into the early debates on the reading of the papers with the debates they had had that morning, they could not doubt for one moment that the object of those three gentlemen and himself had been most successfully attained. He had therefore much pleasure in seconding the resolutions moved. He should add to the few words he had already said the circumstance that, with the exception of two meetings, he had been at every autumn meeting held by the Institute since its formation; but he did not remember upon any one occasion where the reception had been more cordial, more emphatic, and at the same time more lavish, than it had been upon that occasion. He was quite sure that the members would depart from the wonderful city of Manchester deeply impressed with the reception they had met with.

The motion was then put to the meeting and carried with acclamation.

Mr. S. R. **Platt**, Vice-President, in acknowledging the vote of thanks, said: Mr. President, Sir Lowthian Bell, and gentlemen, I had the privilege yesterday of addressing you, and I can only say now that it gives me, as the Chairman of the Local Reception Committee, the Vice-Chairman, Mr. Webb, and our worthy Honorary Secretary, Mr. Thomas Ashbury, the very greatest pleasure indeed to have received the encomiums that the President of the Iron and Steel Institute has passed upon the efforts we have made to give you a good reception. All we can say is, that we hope you have appreciated our efforts, and that during the rest of the time that you have to spend with us in the various excursions that are to be made, you will be equally as satisfied as you have been up to the present.

Mr. A. **Greiner**, Member of Council, had the honour and the pleasure to propose that the best thanks of the members of the Iron and Steel Institute be given to the President for his able conduct in the chair.

Mr. **Perry F. Nursey** said: Gentlemen, I have very much pleasure in rising to second the resolution which Mr. Greiner has just put to you. I think we may congratulate the President upon presiding over one of the most successful and important meetings we have yet held, and we may certainly congratulate ourselves upon the most successful and courteous manner in which that President has presided over the meeting, so far as it has gone. Like our friend, Sir Lowthian Bell, I have been at all the meetings of this Institute from its inception to the present time with the exception of two, and certainly upon no occasion have we had a more urbane or a more efficient chairman and President than the one who now sits before you. I therefore have extreme pleasure in seconding this vote of thanks to Sir William Roberts-Austen, and I am sure it will be carried by you with cordial approbation, and not less with a certain amount of strong personal and kindly feeling. It hardly needs to be put to you, but as a matter of form I do it, and I ask you to give a cordial and hearty vote of thanks to the President, Sir William Roberts-Austen.

The PRESIDENT said: I need not repeat what I have so often said, that it is a great privilege and honour to preside over this distinguished body. The interests in your hands are simply enormous, and it would be indeed wrong if any effort on my part were wanting to make the meeting a success. I need not remind you that we have a very eventful year before us. We shall meet, I hope, about this time next year in Paris, and we must make the best efforts to have thoroughly representative papers and a thoroughly representative meeting, which I trust will be as numerously attended as this one. I thank you very much for the way in which you have received this resolution.

# THEORIES AND FACTS RELATING TO CAST IRON AND STEEL.

Mr. BERTRAND S. SUMMERS sent the following reply to the correspondence on his paper published in the last volume of the *Journal* (1899, No. I. p. 185):—

Replying to Mr. Stead's excellent discussion, the writer can most heartily agree with him upon most of the points. It is with pleasure that Mr. Stead's familiarity with graphitic temper carbon is noted. The author must confess his ignorance on this subject, as he is only familiar with temper carbon through theoretical consideration. He has many times endeavoured to isolate the temper carbon, but up to the present time has failed. Mr. Stead's criticism of denominating temper carbon, "carbon in a transition state towards graphite," is very probably legitimate; his better knowledge on the subject, however, would at least prevail. It is noted with interest that the temper carbon may be made to appear by dissolving the metal in nitric acid, and treating the residue with hydro-fluoric acid. The assumption that temper carbon is able to raise the permeability in cupola metals seems legitimate, in which contention Mr. Stead agrees.

The author regrets that he cannot agree with Mr. Stead's contention that ferro-silicon iron enables a cupola mixture to carry more scrap, as it is contrary to his experience. It is possible, however, that the condition of the scrap, as Mr. Stead suggests, may account for this difference in experience. The scrap mentioned in the paper was a very fair grade of scrap iron; it was, however, principally from light work. It is the author's experience, where the silicon content of the mixture is higher, the iron is more open. This may be due, as suggested in the paper, to a difference in proportions to temper and graphitic carbon. Mr. Stead is quite right in assuming that three and three-tenths per cent. of carbon is above the danger limit mentioned, and as Mr. Stead suggests, in using scrap of this carbon content there is little danger of reducing the carbon below the danger limit.

Mr. Stead's remarks relative to the effect of phosphorus introduces a very interesting phase of the question. Within the past year the author has been using a southern charcoal iron with a content of phosphorus of two per cent. The composition of this iron is rather anomalous. Frequently we have had difficulty in finding anything but a trace of combined carbon in the pig iron as it comes from the furnace. The combined carbon is usually less than one-tenth of one per cent., although the total carbon content is in the neighbourhood of three per cent. Below will be found a few analyses of this iron.

*Analysis of Mannie Pig Iron.*

| | Per Cent. | Per Cent. | Per Cent. |
|---|---|---|---|
| Silicon . . . . | 3·84 | 3·70 | 3·77 |
| Sulphur . . . | 0·003 | 0·005 | 0·016 |
| Phosphorus . . | 2·02 | 2·15 | 1·84 |
| Manganese . . | 0·34 | 0·57 | 0·33 |
| Graphite . . . | 2·82 | 2·67 by HCl<br>2·83 by $HNO_3$ | 3·11 by $HNO_3$<br>3·10 by $HNO_3$ |
| Total carbon . . | 2·92 | 2·83 | 2·93 by HCl<br>3·08 by HCl<br>3·08 by HCl |

To be sure, the iron is high in silicon, but the author has had experience with many irons where the composition was about the same excepting the phosphorus, which was low in every case. About two to three-tenths of one per cent. of combined carbon was found at a minimum. Without making any positive statement, it would seem that the peculiar nature of this iron is somewhat traceable to phosphorus. The author's experience would tend to confirm that of Mr. Stead in the statement that increasing the phosphorus content tends to lower that of the total carbon. There is certainly room in this phase of the question for investigation, and the publication of Mr. Stead's researches on this point may be looked forward to with interest.

There remains but one point further to discuss, which is that of the combination of manganese in iron and steel. The question arises whether the manganese is combined with the iron, carbon, or both. Mr. Stead's citation of the fact that carbon and iron alloyed together does not make a metal suitable for permanent magnets is a very good argument against the combination of carbon and manganese alone.

The author remembers having seen somewhere in the back proceedings of the French Academy mention of the isolation of carbides of manganese, and it may be that some of these compounds have their influence, or it may be, as Mr. Stead says, a combination of the three elements mentioned here. The conclusion of Mr. Hadfield, that manganese is either combined with carbon, or a double carbide of iron and manganese, seems to be legitimate, in which Mr. Stead agrees.

The author wishes to express his appreciation of the discussion of the paper, and he is particularly interested in Mr. Stead's comprehensive study of the possible effects of temper carbon.

# *VISITS AND EXCURSIONS AT THE MANCHESTER MEETING.*

A VERY full programme of visits and excursions was arranged for the Manchester meeting of the Iron and Steel Institute. A thoroughly representative Reception Committee was formed, with the Lord Mayor of Manchester (W. H. Vaudrey, Esq.) as President; Mr. Samuel R. Platt, Vice-President of the Iron and Steel Institute, as Chairman of the Executive Committee; Mr. Henry Webb as Deputy-Chairman; and Mr. Thomas Ashbury, M. Inst. C.E., as Honorary Secretary. The following gentlemen served on the Executive Committee: Messrs. Joseph Adamson (Hyde), Member of the Iron and Steel Institute; John A. F. Aspinall, Horwich (Member); Sir William H. Bailey, Salford (Member); William H. Bleckly, Wigan (Vice-President); S. H. Brooks, Manchester (Member); Samuel Chatwood, Bolton (Member); John Craven, Manchester (Member); W. J. Crossley, Bowden (Member); J. F. L. Crosland, Manchester (Member); Samuel Dixon, Manchester (Member); John Dodd, Oldham; William Dronsfield, Oldham (Member); William Fletcher, Salford (Member); William H. Fowler, Manchester (Member); John M. Gledhill, Manchester (Member); Wallis R. Goulty, Manchester (Member); Joseph Gregory, Carnforth (Member); William Henry Hunter, Manchester; Henry Lawton, Oldham; Henry Lee, Manchester (Member); Sir Joseph Leigh, Manchester (Member); Frederick Monks, Warrington (Member); Sir Richard Mottram, Manchester (Member); Alfred Muir, Manchester (Member); Walter M. Musgrave, Bolton (Member); C. T. Needham, Manchester (Member); W. E. Norbury, Manchester (Member); William J. Parkyn, Dukinfield (Member); T. M. Percy, Wigan (Member); Thomas N. Robinson, Rochdale (Member); Sir E. Leader Williams, Altrincham (Member); and Edward G. Wood, Salford (Member).

There was a very large attendance of members, many of whom were accompanied by ladies. A dinner was given by the Lord Mayor of Manchester to the Council at his Lordship's official residence in the Town Hall on Monday evening, August 14. The proceedings commenced on Tuesday the 15th August in the Town Hall, Manchester, when a meeting of the Council was followed by the General Meeting at 10 o'clock. The members were received and welcomed in very cordial terms by the Lord Mayor, the Chairman, Deputy-Chairman, Honorary Secretary, and members of the Reception Commiteee. The chair was then taken by the President, Sir William Roberts-Austen, K.C.B., when the business of the meeting was proceeded with. The meeting adjourned at 1 o'clock, and at 2.10 P.M. a large party of members left by special train, kindly provided by the Lancashire and Yorkshire Railway Company, to visit their Locomotive Works, Steel Foundry, &c., at Horwich. At 1.45 P.M. on the same day there was an alternative excursion to visit the Simon-Carvès coke-ovens at Barnsley, and for this purpose a considerable number of members were taken by special train, kindly provided by the Great Central Railway Company, whilst luncheon was served *en route* by invitation of Messrs. Simon-Carvès, Limited.

At 8 P.M. on the same day a brilliant reception and conversazione was given by the Lord Mayor and Lady Mayoress in the Town Hall, which was magnificently decorated for the occasion. On Wednesday, August 16th, the General Meeting was resumed, and the reading and discussion of papers was proceeded with, after which the usual votes of thanks brought the meeting to a close. At 2 P.M. a very large party of members and ladies left the Town Hall in omnibuses kindly provided by the Reception Committee to visit the Manchester Ship Canal. The party embarked upon two vessels, which steamed through the Pomona Docks, along the Canal to the famous Barton Swing Aqueduct of the Bridgewater Canal, which crosses the Ship Canal. The party then returned to No. 7 Dock, Salford, where they arrived about 5 P.M., and were hospitably entertained to afternoon tea by the Ship Canal Directors, leaving shortly afterwards in omnibuses for the Town Hall. In the evening at 7.30 the members and ladies were entertained at a special performance at the Theatre Royal (Manchester) of "The Great Ruby." The theatre was beautifully decorated in honour of the occasion, and lavish hospitality was dispensed by the Reception Committee during the evening, the whole entertainment being a great success and highly appreciated by the members and the ladies accompanying them.

Two excursions were arranged for Thursday, August 17th—one to visit the works of Messrs. Platt Brothers & Co. at Oldham, and those of the Pine Mill Company at the same place, and the alternative visit to the boiler-works of Messrs. Galloway, Limited, at Ardwick, and the cotton mills of Messrs. Richard Haworth & Co. at Ordsal. The first party left No. 4 platform of the Victoria Station at 9.35 A.M. in a special train, kindly provided by the Lancashire and Yorkshire Railway Company, for Oldham, where on arrival they were taken over the very extensive engineering works of Messrs. Platt Brothers. The members were afterwards entertained to luncheon by the firm. A visit was then made to the cotton-mills of the Pine Mill Company. The second party proceeded by omnibuses provided by the Reception Committee to the boiler-works of Messrs. Galloways, Limited, and, after inspecting the works, were entertained by the firm at luncheon. The party then visited the cotton-mills of Messrs. Richard Haworth & Co., Limited, at Ordsal, and afterwards proceeded to the Peel Park Art Gallery to attend a reception and garden-party given by the Mayor and Mayoress of Salford (Alderman and Mrs. Rudman), where they were joined by the party visiting Oldham and by a large number of ladies. In the evening the members were invited by the Reception Committee to a smoking concert in the Hulme Town Hall, which was very largely attended and greatly enjoyed by the members, the musical programme being excellent. On Friday, August 18th, a large number of members and ladies left at 9.10 A.M. by special trains, kindly provided by the Midland Railway Company, to visit Chatsworth and Haddon Hall, calling at Belle Vue to visit the machine tool works of Messrs. Kendall & Gent. At Chatsworth the party were entertained at luncheon by His Grace the Duke of Devonshire, who was represented by Mr. Victor Cavendish, Member of Council of the Iron and Steel Institute. The party was conducted over the Hall by Mr. Cavendish and by Dr. Wrench, and afterwards drove to Bakewell, where tea was provided by kind invitation of the Reception Committee. Shortly afterwards they returned to Manchester by special trains. A limited number of members proceeded at 9.55 A.M. the same day by special train, kindly provided by the London and North-Western Railway Company, to visit the Crewe Works of that Company. They were met by Mr. F. W. Webb and conducted over the extensive establishment, and were afterwards entertained at luncheon by kind invitation of the Company, leaving in the afternoon for various parts of the country. This brought a highly successful, interesting, and instructive series of meetings and excursions to a close, the members being loud in their expressions of gratitude for the excellence of the arrangements made for their comfort, and for the unbounded kindness and hospitality shown by every one concerned in the Institute's third visit to Manchester. A large number of works in the district were thrown open to members during the meeting, and members were kindly invited to avail themselves of the privileges of the Arts Club, the Brazenose Club, the Carlton Club, the Conservative Club, and the Reform Club.

## PUBLIC BUILDINGS AND INSTITUTIONS.

### THE MANCHESTER TOWN HALL.

The Town Hall was begun in 1868, and was formally opened in 1887. The total outlay to March 1897 was £1,062,497, 17s. 11d. The area covered by the Town Hall is 8648 square yards. The length of Albert Square façade is 387 feet. The total frontage to streets is 1159 feet 9 inches. The height of tower is 280 feet 7¾ inches. The height of tower to top of ball is 286 feet 5¼ inches. The ball, diameter 2 feet 7 inches, 29 spikes 6¾ inches long; weight, 2 cwt. 21½ lbs. Diameter of clock dial, 16 feet. Size of large room, 100 feet by 50 feet. Height of large room, 58 feet. Length of suite of State apartments, 300 feet. Number of rooms, 314. Length of corridors on ground floor, 750 feet. Length of piping of heating apparatus, about 40,000 feet (over 7½ miles). The bells number 21; weight, 34 tons 5½ cwt.; weight of former great bell (taken down in 1882), 6 tons 9 cwt.; weight of present great bell, 8 tons 2 cwt.; height of ditto, 6 feet; diameter of ditto, 7 feet 7½ inches. The total cost of bells and clock to March 1881 was £6985, 6s. 3d. The organ, by M. A. Cavaillé-Coll, has 4 manuals, 1 pedal clavier; compass, 5 octaves; compass of pedals, 2½ octaves; 3428 pipes; 52 speaking registers, stops, and 22 accessories. Cost of organ, case, and blower, £5269, 13s. 6d. Circular staircases: Princess Street, English granite (Shap); Lloyd Street, Irish granite (North of Ireland); Cooper Street, Scotch granite (Dalbeattie). Barrels of carillon pricked for 31 days. The City Plate, presented by the citizens through Mr. Alderman Curtis, numbers 74 pieces, weight over 10,000 oz., cost £7000. Cost of the Mural Paintings (12), by Mr. Ford Madox Brown, in large room, £4500. The subjects represented are:—(1) The building of the Roman Fort at Mancunium. (2) The baptism of Edwin, King of Northumbria and Deira, at York, A.D. 627. (3) The expulsion of the Danes from Manchester about the year 910. (4) The establishment of Flemish Weavers in Manchester, A.D. 1363. (5) The trial of Wiclif, A.D. 1378. (6) The Proclamation regarding

Weights and Measures, A.D. 1556. (7) Observation of the Transit of Venus, by William Crabtree at Broughton, A.D. 1639. (8) Humphrey Chetham's Life Dream. (9) Bradshaw's Defence of Manchester, A.D. 1642. (10) John Kay, Inventor of the Fly Shuttle, A.D. 1753. (11) The Opening of the Bridgwater Canal, 1761. (12) John Dalton collecting Marsh Gas.

## THE MANCHESTER CATHEDRAL.

The Cathedral, the old Parish Church, was founded in the early part of the fifteenth century. It is open at all times. Among the monuments in the Cathedral there is one to the late Bishop of Manchester (Dr. Fraser), who received the Institute on the occasion of the former visit in 1875.

## THE ROYAL EXCHANGE.

The Royal Exchange was opened complete in 1874. It is by far the largest room in the world devoted to commercial purposes. The area of the room is 4405 square yards. The reading gallery contains 420 square yards, and the portico 463 square yards. The length of the room from Cross Street to Exchange Street is 206 feet, and the width from Bank Street to Market Street is 192 feet. The clear width of the central area under the dome is 96 feet. The height from the floor to the crossbeams under the dome is 60 feet, and from floor to the summit of the dome is 125 feet.

## THE MANCHESTER CORN, GROCERY, AND PRODUCE EXCHANGE.

The original Exchange was built in 1837, and then covered 600 square yards of land. It has been enlarged three times, the last enlargement being completed in 1893, when the accommodation was doubled. It now covers 2500 square yards. In point of area it is one of the largest Exchanges in the United Kingdom, and as a Grocery and allied Produce Trades Exchange it holds a unique position. During the first twenty to thirty years of its existence the building was one of the largest in the city, and was used as a Chapel, a County Court House, and for balls, banquets, and public meetings. The Exchange is now undergoing a further alteration, and is being re-roofed with a steel and glass roof without interruption of business. The design of this roof is generally to follow the triangular shape which the Exchange is ultimately to assume, the centre being surmounted by a dome about thirty feet in height, the whole rising to a height of about 90 feet. The total cost of the Exchange and the surrounding buildings when completed will be about £350,000.

## CHETHAM'S HOSPITAL AND LIBRARY.

The venerable pile of buildings known as Chetham's Hospital and Library is situated opposite the Cathedral, and is approached through a gateway surmounted with the arms and motto of the founder, Humphrey Chetham. The building, originally the Baron's Hall, was rebuilt about 1422 by the Baron de la Warre, and by him handed over as a residence to the Warden and Fellows of the Collegiate Church he established here in that year. They held it until 1547, when, on the dissolution of the College, it was granted to Edward Stanley, Earl of Derby, by Edward IV., and in that family it remained for nearly a hundred years. On the refounding of the College by Queen Elizabeth, the then Earl allowed the famous Warden Dee the use of it. During the Great Rebellion it was put to various uses, such as a barrack, a powder magazine, and a conventicle; and after being neglected and allowed to fall into decay, was purchased from the Derby family by the feoffees appointed under Chetham's will, who were incorporated by Royal Charter dated November 20, 1665. The directions of the founder were that the Institution should support and educate forty poor boys, to be selected from the townships of Manchester, Salford, Crumpsall, Droylesden, Bolton, and Turton. The number of boys was doubled in 1779, and is now ninety. The building is rich in old furniture, and the audit and reading rooms are exceptionally fine, while the hall and kitchen are well worth a visit. The Library was founded at the same time. £1000 was bequeathed for the purchase of books, and £100 for a building wherein to house them, for the augmentation of which Chetham devised the residue of his personal estate, after the payment of certain legacies. It is freely open to all comers, whether resident or not, and contains over 43,000 volumes. The collection is exceedingly valuable, being very strong in theological, historical, and antiquarian literature, besides containing many magnificent works on art and natural history, with numerous valuable and fine MSS. The greater part of the collection has been purchased from time to time under the superintendence of the feoffees, the remainder presented by various donors. The most important gift was the Byrom collection, bequeathed by the late Miss Atherton, of Kersall Cell, descendant of the collector, Dr. John Byrom, F.R.S., who lived in the middle of the last century, and was well known as a stenographer and poet. This collection numbers over 2000 volumes, and includes many valuable MSS. and early printed books. Amongst the most notable possessions of the Library may be mentioned the MS. Flores Historiarum of Matthew Paris, partly in his handwriting; a unique MS. of Early English Poetry, containing Torrent of Portyngale, Ipouradon, &c.; a Commentary on the Lord's Prayer, written by Bradford the Martyr, together with his Bible; Voragine's Golden Legend, by Caxton; the first edition of the Ordinary of Christian Men, by Wynkin de Worde, with many other examples of his press; Tyndale's New Testament, by Marten Emperowr, 1534; fine copies of the third folio Shakespeare; the *editio princeps* of Homer, and the 1517 edition of Tewrdannckh; and the most perfect copy known of Coryat's Crudities. Amongst modern works may be named the Historical Collections of Pertz, Muratori, Dom Bouquet, Langebec, and the publications of the French Historical Society; Dugdale's Monasticon, by Caley and others; nearly all the great county histories, such as Nichol's Leicestershire, Eyton's Salop, Hodgson's Northumberland, &c.; Gould's Birds, Bateman's Orchids, Piranesi on Rome; with a complete set of the famous copies of the Fathers, known as Migne's Patrologia. Mr. W. T. Browne, the Governor and Librarian, is always pleased to show the building and its treasures to visitors. The Chetham Society and the Lancashire and Cheshire Antiquarian Society hold their meetings in this building.

## PEEL PARK, ROYAL MUSEUM, AND LIBRARIES, SALFORD.

Peel Park is situate at the north-west part of the Township of Salford, and consists of 37½ acres of land, the upper portion of which is laid out in flower-beds, lawns, and walks, having marble statues of Her Majesty the Queen, Prince Consort, Richard Cobden, and one in bronze of Mr. Joseph Brotherton, the first Parliamentary representative of Salford. On this part of the ground stands the original mansion of "Lark Hill," and subsequently converted into a Public Free Library and Museum, to which (north and south) wings have been added, and also a Gallery of Fine Art and a Reading Room on the west side, called the Langworthy Gallery. The lower portion of the Park contains the Flower Garden, Artificial Lakes, extensive Bowling

Green, Lawns, Playgrounds, and Gymnasium. On the north side of the Park there has recently been added 25 acres of ground tastefully laid out as a Recreation Ground for Children, and presented to the Corporation by the "David Lewis Trustees." There are three more parks in different parts of the Borough, containing in all 46 acres of ground, and also 21 acres of moorland in Kersal, Higher Broughton, together with 16 playgrounds for children, of different dimensions, placed in the midst of the denser portions of the Borough.

The Peel Park, purchased by public subscription, was opened on the 22nd August 1846, and the mansion which stood on the ground was opened as a Public Free Library on 9th January 1849, and as a Museum some months later in the same year. From time to time additions have been made to the building. In the Reference Library (the first rate-supported and municipally-governed Public Free Library in the kingdom) are some 30,000 books, covering every department of knowledge. In addition, there are five Lending Libraries and Reading Rooms, as well as two Reading Rooms which are not Libraries. Another Branch Library and Reading Room is about to be erected. The total number of books issued from the Libraries is about 400,000 per annum; and the yearly number of persons attending the Reading Rooms approximates 980,000. The number of public uses made during the past year of the Museum and Art Galleries and Libraries and Reading Rooms total up to 1,515,460—a number which exceeds by more than eleven times the reading population (fourteen years and upwards) of the Royal Borough of Salford. The main entrance hall of the Museum and Art Galleries contains plaster casts of antique sculptures and some of modern works. Inserted in the walls of the main staircase are some casts of Assyrian sculptures from Nimrud, which are restored in colour. Here are also casts of portions of the frieze, and of some of the metopes from the frieze of the entablature, of the Parthenon at Athens. In Room A are portraits of men of local eminence and of others of wider fame. The cases are chiefly given up to the exhibition of specimens illustrating the various processes of manufacture in different industries, the cotton and the indigo collections being, perhaps, the most striking and complete. The principal objects of art are in Room B, the Langworthy Gallery. Here are many paintings by some of the best known artists, among them being P. H. Calderon, R.A.; G. F. Watts, R.A.; E. M. Ward, R.A.; Mark Fisher; Leslie Thompson; Thomas Faed, R.A.; William Linnell; William Bradley; Anderson Hague; Joseph Knight; Keeley

Halswelle; R. Ansdell, R.A., &c. The collection of original marble sculptures in the centre of the room will be noticed. They represent the works of such men as J. W. Swynnerton, John Bell, R.A., E. Davies, H. M. Imhöf, &c. In Room C are arranged the Ethnographical collections, illustrating by means of their weapons, tools, clothing, utensils, ornaments, &c., the manners and customs of various peoples in different countries throughout the world. The collections commence with pre-historic man, and pass forward in time through the Stone, the Bronze, and Historic Periods to the present day. Thence the specimens are arranged according to the geographical distribution of the peoples or races they represent. Paintings of various schools, and some modern paintings of considerable historic interest, are hung on the walls. Leaving this gallery, and turning down the steps on the right, the visitor passes some cases containing plaster casts of fictile ivories, which are arranged in chronological order and according to the schools which produced the originals. Here also will be seen some portraits, and many reproductions of engravings from the works of Turner and of Claude Lorraine. There are, besides, several paintings, drawings, maps, &c., of great local interest. In a large case is a fine specimen of the bull fur seal. In Room D is exhibited a collection of British birds; and the adjoining room, D, contains one of birds of foreign countries, a foreign conchological collection, and some interesting specimens of corals. Returning downstairs, and turning to the right, the rooms F and G, in which are arranged the Mineralogical and Geological collections, will be found. Passing into Room G, the series of geological specimens begin with those representing the oldest rock formations; thence the composition of the crust of the earth is traced upwards to the most recent rock formations, and the series terminate in Room F, with a collection of specimens of prehistoric tools and implements.

## THE ROYAL TECHNICAL INSTITUTE, PEEL PARK, SALFORD.

The Royal Technical Institute, which was established to provide instruction in those branches of knowledge which have a direct bearing upon the leading industries in the district, was opened on 25th March 1896.

The total cost of the building was £61,000, and that of the equipment was over £20,000. The annual income of the Institute exceeds £9500. The Institute has a very imposing appearance, being about

311 feet in length and 100 feet high. Accommodation is provided for 2500 students.

The whole building is lighted with electricity supplied from the Corporation mains. The heating and ventilation are carried out in an effective and rather novel manner. In the basement are two large Lancashire boilers, 27 feet long and 7½ feet in diameter. These are used not only for supplying power to the various departments, but are also used for heating and ventilating purposes. About 30 yards in front of the building is a large ventilating shaft, built to harmonise with the building. This is the fresh air inlet. It is connected with the basement by a culvert through which the air is drawn by four fans. The air is purified by passing through a wet screen. Two ducts run the whole length of the building under the corridor in the basement. Some miles of steam coils are placed in the upper of these ducts, so that the air which enters this duct is thoroughly heated. The other duct supplies the cold air. From these ducts the air is propelled into all the rooms at will, and, by pulling a chain in the room, the temperature may be regulated. The foul air is removed through ventilators in the several rooms, and is carried along special channels to the ventilation shaft, where it is expelled by means of fans.

## THE OWENS COLLEGE.

The Owens College was founded under the will of John Owens, Esq., merchant in Manchester, who left the sum of nearly £100,000 for the purpose. The present buildings were opened in 1873. On the immediate right of the main gateway are the Museum buildings and the main staircase leading up to the Council Chamber, in which there is a marble relief of Socrates and his pupils by the late Mr. Harry Bates. On the left of the entrance the structure in course of erection is the Whitworth Hall, a gift to the College by Mr. Chancellor Christie as legatee of the late Sir Joseph Whitworth. After passing through the archway and entering the front quadrangle, on the right are seen the Beyer buildings, containing lecture-rooms and laboratories for the study of zoology, botany, and geology. They are so called in memory of Charles Frederick Beyer, of Messrs. Beyer, Peacock & Co., by whose munificent bequests the College has been so largely benefited. On the left of the front quadrangle is the new Christie Library, the personal gift of Mr. Chancellor Christie. The ground floor of the Library contains works on theology, languages (ancient and modern), history, including the collection of the late Professor Freeman, law and political economy. On the first floor is the Reading Room, in which are the works of general reference; it contains portraits of the late Duke of Devonshire, Mr. Christie, the donor of the library, Dr. Ward, late Principal of the College, and the late Dr. John Hopkinson; busts of Mrs. Gaskell, the late Principal Greenwood, John Dalton, and others; and a first folio Shakespeare, which was given to the College by Mr. Edward Donner in memory of the late Mr. Thomas Ashton. In the top floor are the scientific collections, including the Marshall Memorial Library. The main front block is occupied by lecture-rooms for the Arts Department and for the Physics and Engineering Departments, the rooms of the Women's Department, and the College offices. In the Professors' Common Room are portraits of former Professors and Lecturers of the College. The basement of this part of the College is almost entirely occupied by the Physical Laboratories. A Dynamo-House has been erected outside, provided with a Crossley gas-engine and also one of Compton and Wilde's dynamo machines. A new Physical Laboratory is in course of erection on the north side of Coupland Street. Behind the main block in the back quadrangle are the Chemical Laboratories, both quantitative and qualitative, which together afford room for 100 students. There are besides a laboratory for Medical evening students, accommodating 50 students, and the Schorlemmer Laboratory for Organic Chemistry in memory of the late Professor Schorlemmer, F.R.S., which also holds about 50 students. The Whitworth Engineering Laboratory, also in the back quadrangle, was chiefly erected by the liberality of the residuary legatees of the late Sir Joseph Whitworth. The appliances in the laboratory are complete for steam and engine trials, testing materials, experiments on mechanical fundamental actions, and the stndy of the action of tools and of the materials for construction. The Laboratory has quite recently been enlarged through the generosity of many of the engineering firms in Manchester. Beyond the back quadrangle is situated the Old Medical School, erected at a cost of £26,000, and the New Medical School buildings (opened in 1895), which cost £50,000.

# NOTES ON WORKS AND PLACES VISITED.

## ENGINEERING WORKS OF THE LANCASHIRE AND YORKSHIRE RAILWAY COMPANY, HORWICH.

These works are situated about 18 miles from Manchester, in a north-westerly direction, and were commenced in 1886 for the purpose of repairing and renewing the rolling stock, and carrying out the mechanical engineering work of the railway. The land enclosed for the works comprises about 116 acres, and the covered area of the workshops is 21 acres, in which 3600 men and boys are employed. The works comprise iron, steel, and brass foundries; forges, rolling-mills, and smithies; boiler, fitting, machine, erecting, millwrights', pattern, points and crossing, signal, and paint shops; furnace gas-producers, electric light and power houses, and gasworks for lighting purposes. A Mechanics' Institute, Cottage Hospital, and Recreation Grounds have been provided for the use of the employees.

## COKE-OVENS AT WHARNCLIFFE SILKSTONE COLLIERY.

*Simon-Carvès By-product Coke-ovens.*—At this colliery one of the most modern installations of by-product coke-ovens on what is known as the Simon-Carvès system was started to work in February last. The installation consists of one battery of 35 ovens and the necessary apparatus and plant for recovering the tar, ammoniacal liquor, and crude benzol; also a plant for the manufacture of sulphate of ammonia. By the Simon-Carvès system the coal is converted into coke by heat transmitted to the coal through the oven walls, such heat being obtained by burning the gases evolved from the coal after the tar, benzol, and ammonia have been carefully extracted.

*The Ovens.*—The ovens are in the form of long high narrow chambers of brickwork with partition walls containing horizontal flues. There are also flues underneath the sole of the ovens. The flame, after passing from the tuyeres along the whole length of the flue under the sole of the oven, ascends by vertical flues to the top horizontal flues, and then descends in a zig-zag direction along each side of each oven, finally passing into the heat recuperator, where the waste heat is utilised for heating the air necessary for the combustion of the gases.

*Ovens Heated Bottom and Sides.*—The coke-ovens are thus heated at the bottom and also evenly at the sides, so that the coal becomes rapidly and completely coked.

*The Recuperator.*—The recuperator is entirely self-acting, and consists of five flues arranged side by side underneath the coke platform and parallel with the range of ovens. Three of these flues serve for the conduct of the air required for combustion of the gases, and the two intervening flues convey the hot waste gases coming from the oven flues.

*Economy of Recuperator.*—With this waste heat, after the gases have completed their service in the ovens, the air of combustion is raised continuously and automatically, and free of cost, to a high temperature before using it—a very great advantage, seeing that the quantity of air required for perfect combustion of the gas is about ten times larger than that of gas.

*Economy and Advantages of Large Ovens.*—Each of these ovens takes about ten tons of coal at a charge, and they are the largest by-product coke-ovens in this country or abroad. The advantages of these large ovens are, that a larger quantity of coke is produced at the same expense in labour as for a small oven, and also a diminution in loss of heat and in loss of by-products owing to less frequent charging for a given quantity of coke. To supply these ovens about 1400 tons of coal weekly, or say 70,000 tons of coal per annum, are required.

*Increased Percentage of Coke.*—In addition to the valuable by-products recovered from the gases in the process of coking, the quantity of coke made by this system from the same quantity of coal is, as is well known, about 50 per cent. more than what is obtained with the old-fashioned Beehive ovens—an important factor in view of the present demand for blast-furnace coke.

*Process of Manufacture.*—The process at the Wharncliffe ovens is as follows:—The ovens are charged with coal by holes at the top from coal tubs running on rails, the coal being evenly distributed by levelling rakes introduced through openings in the doors, the latter being kept closed and tightly luted while the coal charge is being coked. From the top of the oven rises a gas ascension pipe through which the gases are drawn by means of exhausters, and patent gas valves are provided for the purpose of isolating each oven while discharging the coke and charging coal. When the ovens are working the gases pass through these valves and the deposits are collected in hydraulic mains. The gases, after passing through the valves and hydraulic mains, pass through powerful condensers for the purpose of being still further condensed and cooled. After leaving the condensers the gases pass first through scrubbers to complete the recovery of ammonia, and then through other scrubbers for the recovery of benzols. The coke is pushed out from the back of the oven on to the coke platform by means of a coke-ram worked by a portable steam-engine running on rails in front of the ovens.

*Introduction of the Simon-Carvès System.*—This system of coke-ovens with recovery of by-products, which is now being developed by the Simon-Carvès By-product Coke-oven Construction and Working Company, Limited, of Manchester, was first introduced by their chairman, the late Mr. Henry Simon, of Manchester, at Messrs. Pease's collieries near Darlington in 1882. This original installation, after seventeen years of continuous working, is still giving satisfaction.

*Durability of By-product Coke-ovens.*—A large number of these by-product coke-ovens have been built not only by Messrs. Pease, but also at various other collieries and blast-furnace works in this country, and similar installations to the one described above are now being built for the Barrow Hematite Steel Company, John Brown & Co., J. & J. Charlesworth, and the Monckton Main Coal Company. These ovens, the oldest by-product coke-ovens in England, have fully and conclusively demonstrated the small cost in maintenance which properly constructed by-product coke-ovens entail—a circumstance which cannot be appreciated until ovens of this class have been at work for a long number of years.

*New System of charging Coke-ovens.*—At the last-mentioned colliery the Simon-Carvès Company is introducing a new mechanical apparatus (which has not so far been used in this country) for compressing the coal and charging it into the ovens. This new feature is expected to produce an economy in working the ovens, give an increased output of coke of improved quality, and an increase in quantity of by-products.

## THE MANCHESTER SHIP CANAL.

The Manchester Ship Canal is 35½ miles in length, and has been excavated throughout to a depth of 26 feet. The depth of lower sill of Eastham locks below Old Dock sill is 23 feet. The depth of water on all the upper sills of locks, in both estuary and inland portion of canal, is 28 feet. This will enable the depth of water in the canal to be eventually made 28 feet throughout, if found requisite. The bottom width at the full depth is 120 feet, with the following exceptions :—

(*a*) At the curve at the Weaver outfall the width at the full depth is 140 feet, and is now being dredged to 180 feet, and at the bend at Runcorn approaching the Runcorn railway bridge it is 150 feet. (*b*) For a distance of about 2½ miles, between Latchford Locks and Partington coal basin, the bottom width is at present only 80 to 90 feet, and large vessels are not allowed to pass each other on that portion of the canal. (*c*) From Barton aqueduct to the Manchester Docks the bottom width is 170 feet. The tidal portion of the Ship Canal from Eastham to Latchford Locks (21 miles) is maintained at a level of 9 feet 6 inches above mean tide level. When the tide rises above that level it flows into and out of the Canal.

The locks are the following:—

Eastham—Large lock, 600 feet by 80 feet; medium lock, 350 feet by 50 feet; small lock, 150 feet by 30 feet (width of Canal 300 feet).

Latchford—Large lock, 600 feet by 65 feet; small lock, 350 feet by 45 feet; fall, 16 feet 6 inches (width of Canal 290 feet).

Irlam—Locks same as Latchford; fall, 16 feet (width 370 feet).

Barton—Locks same as Latchford; fall, 15 feet (width 330 feet).

Mode Wheel—Locks same as Latchford; fall, 13 feet (width 330 feet).

The total fall from level of water in Manchester Docks to level of tide rising 14 feet 2 inches above the old dock sill at Liverpool, 60 feet 6 inches, this being the ordinary water-level in the Canal between Eastham and Latchford. There are the following subsidiary locks:—Weston Marsh, 229 feet by 42 feet 8 inches; Weston Mersey, 600 feet by 45 feet; Bridgewater, 4000 feet by 45 feet; Runcorn (old quay), 250 feet by 45 feet; Walton, 150 feet by 30 feet; Twenty Steps, 85 feet by 19 feet 6 inches.

The height from the normal water-level in Canal to underside of girders in the seven fixed bridges over the Canal leaves a clear headway of 75 feet.

The Manchester Dock railways are 40 miles in extent, and completely intersect the dock estate. The total length of railways of the Company already completed at the docks and at many points alongside the Ship Canal is upwards of 90 miles. They are constructed around the quays and wharves of the Manchester Docks (with large and convenient gridirons and marshalling sidings), the Partington coal basin, and alongside the Canal at Latchford, Acton Grange, down to old quay works, Runcorn, Runcorn Docks, and also at Ellesmere Port, and other places.

In addition to the important warehouses, &c., on the banks of the Canal, there is an American-built grain elevator, with a capacity of 40,000 tons (or 1,500,000 bushels), having 226 bins, and the machinery is on such a scale that the following operations can all be performed simultaneously: (*a*) discharging from vessels in the dock at the rate of 350 tons per hour; (*b*) weighing in the tower at the water's edge; (*c*) conveying to the house and distributing into any of the 226 bins; (*d*) moving grain about within the house for changing bins or delivery, and weighing in bulk at the rate of 500 tons per hour; (*e*) sacking grain, weighing, and loading sacks into 40 railway waggons to carts simultaneously; (*f*) conveying from the elevator into barges or coasters at the rate of 150 tons per hour if in bulk, or 250 sacks per hour if bagged.

An important feature in the house is Metcalf's Patent Dryer, used in America with most satisfactory results. The dryer is capable of drying 50 tons of grain at each operation, and grain can be moved to or from the dryer from or to any bin in the house.

## MESSRS. PLATT BROTHERS & CO., LIMITED, OLDHAM.

The works of this firm are the largest textile engineering works in the world. They are 55 acres in area, exclusive of the collieries, and comprise Hartford Forge, Hartford Sawmills, Hartford New Works, Hartford Old Works, the Werneth Spindle Works, and three collieries. They afford employment to 11,000 to 12,000 operatives, the New Works alone affording employment to 5850. This mammoth enterprise has grown from modest beginnings. Founded in 1821 by Mr. Henry Platt, who shortly after entered into partnership with Mr. Elijah Hibbert, the business has been constantly progressive, and from time to time different members of the Platt family joined as partners. In 1854 the style of Platt Brothers & Co. was adopted, and in 1868 the firm was formed into a private limited company in order to give a number of the heads of departments and agents a direct interest in its extensive operations. At Hartford Forge all the malleable iron used by the firm is produced. The sawmills cover over 8 acres, and are equipped with sawing plant of the firm's own make, wood-working machinery of the most modern type, and a comprehensive system of steam travelling cranes, overhead and otherwise. The machinery is driven by a magnificent 400 horse-power compound horizontal engine; and the sawmills, which are lighted by electricity, are capable of turning out as many as 360,000 cubic feet of log timber annually.

Very extensive timber-drying stores are situated some little distance off, and it is not uncommon to find 360,000 to 400,000 cubic feet of cut timber "steered" in the yard; and the packing-case shops represent in themselves quite a large undertaking, as with their full complement of sawing and wood-working machinery, they are capable of metamorphosing as many as 4,800,000 superficial feet of deal into packing cases in the course of a year.

At the Hartford New Works, situated at Werneth, a suburb of Oldham, are spacious pattern-shops and seven large foundries, any one of which is equal in dimensions and capacity to many a distinct foundry establishment. These foundries are served by seven cupolas, the output of castings averaging about 640 tons weekly, and being mostly of small size, moulding machines are largely used. The core drying stores are conveniently situated in the centre of the foundries, the spacious dressing-shops being centrally placed, and from them the castings are distributed throughout the works by seven of the firm's own locomotives. The steel plant is undergoing extension, and an open-hearth furnace is now being erected for making steel wheels and a heavier class of castings than can be economically made from crucible cast steel. The work of the top roller department is conducted in the ground floor of an immense block of workshops, four storeys high, which contain probably the largest aggregation of lathes and machine-tools in existence. In the bottom roller department the rollers are fluted, as many as 13,000 lengths of fluted rollers being produced weekly. There is an extensive series of grinding-shops, with an ample complement of emery and other machinery; and the smiths' forge and stamping department is another extensive and ever-active section of the works, especially well provided with labour-saving and modern smiths' machinery, no process being left for hand labour which mechanism can accomplish. In the vast machine-shops, where the cast-metal pieces alone are manipulated, there are more than 400 lathes; and as this is only one of a series of similar shops comprised in one block, the whole together may be regarded as unique amongst the machinery-producing establishments of the world. Then another similar series of shops is devoted to the manipulation of wrought-iron pieces—shaftings, studs, screws, and the like; and another grinding-shop is passed through *en route* to a department fitted with heavier machinery, capable of dealing with from 30 to 40 tons of finished shafting weekly. The mill-wright shop is one more hive of industry; the loom-shops constitute a further busy series.

The carriage department, where the carriages for the mules and twiners are produced, comprises a number of long and spacious workshops, fitted, for the most part, with special sawing, boring, tenoning, jointing, and other automatic wood-working machinery, including some of the most cleverly contrived labour-saving appliances that can be applied to the manipulation of wood. Elsewhere the iron, brass, and other carriage mountings are prepared and fitted to the carriages, which in another shop are finished, painted, packed, and lowered through hatchways on to trucks below. In another department the wooden laths for looms are manipulated and finished ready for fitting to the looms. And then come the mule shops, where the headstocks of the self-acting mules are erected. The framework and other castings from the foundry are put together in one shop, and the wrought-iron portions in another, preparatory to their being fitted together in a third shop, one side of which is monopolised by the roller-beam portions, and the other by the headstocks. The immense block of shops in which the work of this department is carried on is 363 feet long, and contains some hundreds of special boring, sawing, planing, and other machine tools, being provided also with lifts and other appurtenances. The special machinery in all departments of the works has, for the most part, been invented and manufactured by the firm to suit their own requirements. The stores and packing galleries, the case-hardening shops, the brass-foundries, the ring spinning and doubling machine rooms—these are a few of the many other departments which space will not permit to particularise, but which, like the firm's general and drawing offices, are on a scale corresponding with that of the other departments. The entire works are intersected by a network of railway.

The Werneth Spindle Works, employing about 1400 workpeople, produce about 35,000 spindles weekly, and something like 1283 gross of bolts, nuts, and screws in the same time. At the Hartford Old Works, situated in another part of Oldham, and employing some thousands of operatives, the machines employed in the preliminary processes of cotton and woollen manufacture are produced. Some idea of the colossal industry which the firm carries on may be gathered from the fact that something like 33,000 tons of iron are consumed in the course of a year.

## PINE MILL COMPANY LIMITED, OLDHAM.

This Company's Mill at Oldham is one of the most modern and best adapted cotton-spinning concerns in the country, has been working something like seven years, and has established a name in the market for producing a super yarn in American from 45s. to 60s. twist, and in Egyptian 60s. twist and from 60s. to 80s. weft. It contains 106,796 spindles, the whole of the machinery being supplied by Messrs. Platt Bros. & Co., Ltd., Oldham, is driven by ropes from a pair of horizontal compound tandem steam-engines, with a capacity of 1800 horse-power, built by Messrs. Buckley & Taylor, also of Oldham, and fed by five boilers of 120 lbs. pressure each, to which are attached Cass's patent coking stokers. The mill is fireproof throughout and fitted up with Witter's sprinkler.

NAWAB SALAR JUNG BAHADUR

## GALLOWAYS LIMITED.

The original firm was established in the year 1790 at Knott Mill, Manchester, as General Engineers, and it is interesting to recall that the first locomotive engine built in Manchester was constructed at these works (1831) for the Manchester and Liverpool Railway; and further that Bessemer steel was here first manufactured by experimental plant laid down in 1858 by Henry Bessemer and Messrs. Galloway. In 1845 Messrs. Galloway introduced their patent "breeches" boiler, namely, with two furnaces joining at the fire-bridges; but a further development of this boiler was patented in 1849, with the top and bottom flue having rows of tubes down the centre to give strength. Hitherto the vertical water tubes had been parallel, being secured to the flue plates by loose iron angle flanges; but at this time the plan was adopted of making them of a taper form, although it was not until 1851 that the "Galloway" tube as now used was developed, namely, with such an amount of taper that the small flange at the lower end would pass through the hole made in the upper surface of the flue to receive the large end of the tube. This improvement removed many practical difficulties in the way of fixing, and was the commencement of a very large trade in the fixing of "Galloway" tubes in existing boilers. In 1860 the flat surface was discarded and the flue made of an oval shape, and at this period the side pockets were introduced. In 1875 a very striking advance was made by constructing the "Galloway" flue with the top and bottom curves struck from one centre, so that by placing the tubes converging towards this centre the top and bottom flanges of the tubes were square to the centre line, and this is the form which practically obtains at the present time, except that for the higher working pressures the boilers are constructed with flues in accordance with a patent taken out in 1894, which provides for the upper and lower plates of the flue being corrugated to special form by hydraulic pressure, the "Galloway" cone tubes being enlarged at the upper and lower ends by special machinery to a proper angle to attach to the said top and bottom flue plates. The rivet-holes in these tubes and also in the flue are drilled by specially designed machinery. The boiler-making trade having assumed such large proportions, in 1872 the branch works in Ardwick were commenced, and, as quickly as possible, the whole of the boiler construction was transferred there, and the arrangement and equipment of the works entirely devoted to deal with this class of work. Machinery of the most perfect kind was adopted for dealing with the various processes, avoiding hand work where at all possible, and the whole of the tools arranged so that the various parts would pass from one operation to another with the least amount of handling. The magnitude of the business will be realised when it is stated that over 10,500 large-sized boilers have been constructed by this firm for working at various pressures, up to and including 225 lbs. per square inch, and that for a large number of years the output has exceeded one boiler per day; in addition, an immense trade is done in the manufacture of the "Galloway" and other tubes, the total number of which is fully 20,000 per annum. There is also an efficient plant for the manufacture of the special forms of welded and flanged work required by various engineers in connection with steam boilers and vessels of all descriptions, as well as for the supply of furnaces, flues, end-plates, connections, stand-pipes, and manholes. At these works a boiler is manufactured complete throughout in all its details, and the whole of the fittings required in connection with their boilers are made by the company at their Knott Mill Ironworks; they are thus enabled to supply a boiler complete, and provided with all its attachments, the whole being made on their own premises, and under their own supervision. The subject of steam generation is one that has always engaged the close attention of the Company, and any development has received their consideration, so that the equipment of their works should always be in the highest state of efficiency, and the quality of workmanship in the most advanced stage of perfection. The machinery at the Branch works is operated by one of Galloway's superposed compound condensing engines, having high-pressure cylinder 14-inch bore, and low-pressure cylinder 24-inch bore, both prepared for a stroke of 3 feet, and indicating about 200 horse-power. Steam is provided by three patent Galloway boilers 30 feet long by 8 feet diameter; but owing to current extensions the necessity has arisen for at least another boiler, which is at present in hand. The boiler-shop, the central bay of which is 530 feet long, has a width of 180 feet, and the test-shop, where the boilers receive the last attention, will, with the addition which has just been commenced, have a length of 330 feet by a width of 60 feet. The boiler-works altogether cover an area of 8 acres, and are adjacent to the London and North-Western and the Great Central main lines, with which they are in direct communication by the Company's siding. Employment is given to upwards of 800 men and boys.

At the Knott Mill Iron Works, which are situated within one mile of the Manchester Royal Exchange, the engineering branch of the business is carried on, being arranged and equipped for the construction of engines and plant of a very heavy description, including rolling-mill engines, blowing-engines, horizontal and vertical engines for textile, flour, paper, and saw-mills, also for printing, cement, brick, water, gas, and electric works, &c., high speed enclosed engines, hydraulic pumps, central condensing installations, patent safety barring gear (steam or hand), &c. The head offices of the Company are at these works, which give employment to 450 men and boys.

## COTTON MILLS AND WEAVING SHEDS OF MESSRS. RICHARD HAWORTH & CO., LTD., ORDSALL LANE, SALFORD.

The firm of Richard Haworth & Company, Limited, Manchester, cotton spinners and manufacturers, is one of the largest concerns in the County Palatine, and since its establishment fifty years ago has become one of the best known firms in the Home, Colonial, and Eastern markets. Cotton cloths of almost every description are manufactured, among which may be named:—Shirtings, long cloths, mediums, sheetings, Wigan twills, Jeanettes, window hollands, flannelettes, &c. &c., for which they have a high reputation. They are also manufacturers of superior qualities of Heald yarns, fish-net yarns, &c. &c., in which they do an extensive trade.

## MESSRS. KENDALL & GENT, VICTORIA WORKS, BELLE VUE.

These works have recently been designed and specially laid down for the construction of machine tools for engineers, and are situated on the south side of the city, adjoining the Belle Vue Station of the Great Central and Midland Railways, to which they are connected by special sidings. They consist principally of a lofty main building devoted to the erecting and fitting shops, about 300 feet long by 150 feet wide, so arranged as to be well lighted from the sides and roof, and are fully equipped with the most modern plant and tools. This building is divided into four main bays, the two centre bays being served by electrically driven cranes, one of ten and the other of twenty tons, traversing the whole length and covering all the heavy tools, as well as serving the loading and unloading department when required. The two other bays on either side, though open to the general works, form really a couple of two-storeyed buildings, the ground floors of which are occupied by machines serving the main working bays. The floor or gallery above is supported on steel girders of uniform section and pitch, so arranged as to afford suitable supports for the main shafts and all the driving apparatus, which are carried by specially designed hangers, arranged to clip the steel girders, and these being of uniform section throughout, allow the hangers to be readily changed to any position as required, the advantage of which is obvious in fixing or rearranging the position of machine tools. The driving throughout is electrical, the power being generated in a central station and distributed to the main shafts and cranes by motors, whilst it also serves for the lighting of the shops and offices. The generating station consists of two three-crank high-speed compound engines, which, running at 480 revolutions per minute with a boiler pressure of 160 lbs., give an output of 100 horse-power each, and are arranged to run independently or parallel, so that either engine can be used either for motors or lighting as desired. The voltage of the installation is 230, and the power is distributed throughout the works mainly by motors of 20 horse-power, driving groups of machines, each group being driven from a main shaft with a motor in the centre. This enables different types of machines to be driven in section, so that the planing machines, boring machines or lathes, &c., can be operated independently as occasion requires. In addition to the general driving, arrangements have been made on every one of the main pillars in the centre of the works for taking off 20 horse-power, so that motors can be used for portable machines. The smithy, pattern shop, and pattern stores form separate buildings, and the works are so laid down that materials arriving by the railway siding are carried to their separate operations in succession, so as to return in a finished condition at the railway siding, which runs across the two main bays in the main building served by the travelling cranes. The whole of the works designed have not been completed, provision having been made for considerable extensions. In course of construction and in operation are many of the most advanced types of machine tools.

## HADDON HALL.

This interesting relic of the Middle Ages belongs to the Rutland family, and is in a remarkable state of preservation, although now uninhabited. The central block, with the banqueting-hall and the culinary offices, belong to the fourteenth century. The entrance tower and the nave and aisles of the chapel are Norman. The mixed house and garden architecture, with the south façade, the terraces, the steps and balustrades, belong to the Tudor period. The hall contains a chapel, a banqueting-hall, a dining-room, a drawing-room, a ball-room or long gallery, and several state bedrooms. The principal room is the ball-room, which is over 100 feet long. In the principal state bedroom a four-poster is shown as the bed of Queen Elizabeth, and afterwards of George IV. The walls are hung with tapestry from the Gobelins manufactory at Paris. In the window recess there is a dressing-table and a looking-glass that belonged to Queen Elizabeth.

## CHATSWORTH HOUSE.

The present palatial residence of the Duke of Devonshire, usually described as "the Palace of the Peak," was commenced in 1687 by the fourth Earl of Devonshire, and was completed in 1706. There had, however, been a former Chatsworth House on the site of the present building, built by the famous "Bess of Hardwick," wife of Sir William Cavendish. In this earlier house Mary Queen of Scots occasionally resided. The present house is in the Palladian style of architecture. The exterior consists of a large rectangular block, erected by the first Duke of Devonshire, and a long wing of one storey, rising to three at its end, added by the last. Ionic pillars rise between each set of gilt-framed windows, those in the centre being crowned by a pediment adorned with the Cavendish arms. The entrance is at the north end of the modern wing, and the visitors are first shown into the sub-hall, a small apartment with a tessellated pavement and a ceiling adorned with a copy of Guido's "Aurora," by Miss Curzon. Passing thence through the north corridor, the great hall is reached, with floor of black and white marble mosaic. A gallery runs round three sides of the hall, above which the walls are frescoed with scenes from the life of Julius Cæsar, by Verrio and Laguerre; the ceiling is painted by the same artist, and is intended to represent Cæsar's apotheosis. The Chapel, which is next shown, is wainscoted with cedar-wood, has a floor of black and white marble in mosaic, and has at its west end an altar of Derbyshire spar, sculptured with figures of Faith and Hope by Gibbes. Above these is "The Incredulity of Thomas," by Verrio. The ascent of two narrow flights of stairs, and a passage through the Etching Gallery, conduct visitors to the State Apartments, which occupy the third storey. These comprise:—

1. The *State Dressing-Room*, with wood carving by Gibbons, and some fine china.

2. The *Old State Bedroom*, containing the canopy of the bed in which George II. died, the coronation chairs of George III. and Queen Charlotte, a wardrobe of Lous XIV., and wall-hangings of leather relieved with rich gilding.

3. The *State Music-Room*, containing the coronation chairs of William IV. and Queen Adelaide. A cabinet of precious stones, including a piece of emerald said to be the largest in the word, and a ceiling fresco representing the story of Mars and Venus.

4. The *State Drawing-Room*, with walls hung with Gobelins tapestry, representing Raffaelle's Cartoons, and a ceiling painted to represent Phaeton driving the Horses of the Sun.

5. The *State Dining-Room*, with some remarkable wood carving in the form of strings of game hanging down on each side of the fireplace, and having on the central table a number of curios, including the rosary of Henry VIII. and its case. The picture on the ceiling represents "The Fates cutting the Thread of Life."

The *Picture Gallery*, which is next visited, contains a large number of famous works by ancient and modern masters; and in the billiard-room beyond is Landseer's "Bolton Abbey in the Olden Time."

The *Sculpture Gallery* contains the "Endymion," and the "Mother of Napoleon," by Canova; Thorwaldsen's "Venus," and Schadow's "Spinning Girl." This room also contains a huge Mecklenburg vase by Canteen, and the largest "Blue John" (fluor spar) vase in existence.

The *Orangery*, which conducts from the house to the gardens, contains some fine sculptures and a huge quartz crystal. In the gardens the principal object is the *Grand Conservatory*, which was the original of the Great Exhibition building in 1851, and which was re-erected here by Paxton. It is nearly 300 feet long, 120 feet wide, and 65 feet high. The *French Garden* is behind the house, and the *Italian Garden* is in front of it. In the churchyard of the little village of Edensor, close by, the late Lord Frederick Cavendish, a former Member of Council of the Institute, is buried. In the church is a stained glass window to his memory, in which the chief figure is that of Christ as "The Man of Sorrows."

## LONDON AND NORTH-WESTERN RAILWAY COMPANY'S STEEL AND LOCOMOTIVE WORKS, CREWE.

These works, which were established in 1843, have gradually grown until, at the present day, they constitute the largest railway works in the world. They give employment to 7500 persons; and to these may be added over 700 engine-drivers, firemen, and others at the steam sheds at Crewe Station. The company have built and own 845 workmen's cottages. They manufacture and supply gas, not only to their own works, but to the whole town of Crewe, and they also supply water to the works and town, the supply being derived from the red sandstone at Whitmore, about 12 miles distant from Crewe. The ground upon which the works stand is about 1½ miles long, and its area is 116 acres, of which 36 are covered in. The works are in close proximity to Crewe Station, the most important junction on the London and North-Western Railway, and 158 miles from London; they are divided into three main groups, which are spoken of as "the Old Works," "the Deviation Works," and "the Steel Works."

At the steel works, in the converting-house, the plant consists of four 5-ton converting vessels in two groups, with the cupolas placed behind them. The converters are manipulated by hydraulic machinery, and hydraulic cranes are used for handling the ingot moulds, &c. Air is supplied to the converters by a pair of horizontal blowing engines, of 450 horse-power, by Hick, Hargreaves & Co., of Bolton. The steam cylinders are 36 inches diameter and 60 inches stroke, and the air cylinders 48 inches diameter and 60 inches stroke. In the Siemens-Martin house there are five 20-ton steel-melting furnaces, and the gas for these, the reheating and other furnaces, is provided by means of

51 Wilson gas-producers, the gas being conveyed to the various furnaces in underground flues. Each furnace is fitted with powerful hydraulic machinery for handling the ladles. The steel-making plant is now capable of producing 50,000 tons of steel per annum. In the cogging and rail-rolling mills the rail ingots as cast are 3 feet 4 inches long and 14 inches square. After reheating they are passed through the cogging-mill five times, which reduces their section to 10 inches by 8 inches. They are then run directly to the three-high rail-mill, whence, after thirteen passes, they emerge as rails over 60 feet long, their weight being 90 lbs. per yard. All the various operations necessary in the handling of the rails, from the time they leave the reheating furnace until they are delivered into the waggons, are effected by steam and hydraulic machinery. The cogging-mill is driven by a pair of vertical reversing-engines, with cylinders 2 feet 6 inches diameter and 3 feet 6 inches stroke, and the rail-mill by a Corliss engine of about 1200 horse power. The other plant consists of various drilling and shearing machines, saws, &c.

The chief other objects of interest in the several departments of the works are as follows:—Point and crossing shop: group of special machines for manufacture of points and crossings. Boiler-shop (where 200 new steel locomotive boilers are made annually, and the necessary repairs to the boilers of over 2700 locomotives effected): hydraulic riveting-machines, boiler-stay tapping-machine, electrical cranes and drills, pneumatic caulking-machine, &c. Flanging-shop: hydraulic presses punching and flanging boiler-plates. Boiler-mounting shop: electrical tube-cutter, &c. Iron-foundry. Tender-shop: hydraulic riveting, and building of tenders and carriage frames. Repairing-shops: horn-block planing machine, valve-facing and cylinder-boring machines, &c. Forge and rolling-mills: plate-mill for rolling boiler-plates; 7-foot saw cutting steel casting gates cold; 8-ton hammer working on crank-shafts; 30-ton hammer slabbing boiler-plates; carriage-tire rolling; fish-plate rolling, punching and straightening, and merchant and guide mill. Steel-foundry. Bolt and nut shop: special group of machinery for forging and finishing nails, rivets, bolts, and nuts. Wheel-shop: group of machines for finishing wheels and axles, electrical cranes, &c. Signal-shop: electrical staff instruments. Paint-shop. Testing-shop; machines for testing tensile strength of plates, hydraulic bending and drifting machine, chain, cement, and oil-testing machines. Millwrights' shop. Joiners' shop and sawmill: special wood-working machinery.

Old Works:—Smiths' forge, smithy, and spring-shop: electric welding-machine. Locomotive erecting, wheel, and fitting shops.

A complete telephonic system connects the offices and the whole of the shops together, thus rendering communication over their large area easy and expeditious. Besides the offices, several of the shops are lighted by electricity, the incandescent system being used for the former and the arc system for the latter. A fire-main, with water at a pressure of 100 lbs. per square inch, is laid through that part of the works where the more inflammable shops and materials, such as the joiners' shop, the saw-mills, and the timber-yard are situated. There are also two hydraulic mains for serving most of the hydraulic machinery at the steel works—one at 400 lbs. pressure per square inch for the ordinary machines, and the other at 2000 lbs. pressure per square inch for the powerful presses. Steam is supplied to the engines at the steel works from 16 stationary boilers, 30 feet long and 7 feet diameter, and from 24 boilers of the loco-stationary type. The former work at a pressure of 80 lbs. and the latter at 100 lbs. per square inch. All these boilers were made at Crewe, of Crewe steel. Besides the ordinary 4 feet 8½ inches gauge railway connecting the various parts of the works, there is a narrow-gauge railway, 18 inches wide, which traverses every part of the works, the total length of it being about five miles. It is worked by small locomotives, which draw trains of strong low-wheeled trolleys, conveying materials and finished work from one part of the works to another.

## MESSRS. JOSEPH ADAMSON & CO., HYDE, CHESHIRE.

These works were established in 1874 for the construction of high-class steam-boilers by the present proprietor in partnership with Mr. Henry Booth, who retired in 1887. They cover about three-quarters of a plot of ground of about four acres, closely adjoining Hyde Station on the Sheffield and Midland Railway, with which they are directly connected by a private siding. They have from time to time been extended to cope with increased trade, and with the heavier weights called for in boiler-work during recent years. In 1883 a new step was taken by the erection of a special shop, 200 feet long by 45 feet span, to contain a 500-ton hydraulic flanging press and its necessary dies, which latter by the growing requirements of the trade have already accumulated to the amount of upwards of 400 tons. This flanging department is engaged, in addition to the special flanged work required in the works, in pressing and flanging plates sent in by other boiler-makers. In connection with the press is a hydraulic accumulator with 12-inch ram and 20-feet stroke, loaded with about 90 tons of pig iron, and supplied by a set of quadruple fly-wheel steam pumps, arranged to stop and start automatically according to the position of the accumulator ram. This hydraulic power is used throughout the works for actuating the riveting machines and cranes, also a smaller press. The pumps are situated in an engine-house built close to the boiler-house; and under the same roof is a Brotherhood air compressor supplying compressed air for the working of the caulking and riveting machines in the boiler-shop, and also the electric power plant, consisting of a 50 horse-power Belliss high-speed engine directly coupled to a Siemens dynamo running 500 revolutions (chiefly occupied with the lighting of the works), and a 75 K.W. dynamo of the firm's own make, directly coupled also to a Belliss engine running 400 revolutions (chiefly occupied with supplying power for the numerous overhead travelling cranes, and also the motors of various sizes, from 50 horse-power downwards, that are used in the different parts of the works for driving individual machines or lengths of line shafting). The boiler-shop proper consists of five bays, each 45 feet span, the first two of which (adjoining the hydraulic press-shop) are occupied by the angle-iron smiths engaged in welding and flanging work for the boiler-shop. The next bay, which may be called the shell-shop, contains, amongst other tools, a plate-edge planing-machine capable of planing plates up to 30 feet long by 6 feet wide on both side and end at one setting, while by carrying the plate forward an indefinite length can be reached. Also two boiler-shell drilling machines, of ten and eleven drills each respectively, arranged to drill both the circular and longitudinal seams. Also a powerful horizontal turning machine, capable of edging plates up to 10 feet diameter and up to 4 feet deep, if required, with an additional boring head for cutting out the flue-holes and the oval holes for manholes. The fourth bay of the boiler-shop is occupied, at the end next the railroad, by punching and planing machines and a small set of bending rolls, all of which are employed in preparing the flue-plates for the subsequent operations in the smithy already mentioned. The blacksmiths are located in this bay, and have at their disposal one 5-cwt. Massey hammer and one 10-cwt. Nasmyth-Wilson hammer. After the flue-plates have been welded and flanged in the smithy they are returned to this bay for drilling and turning, &c., while the end of this bay (nearest the offices and furthest from the railroad) is fitted up with the necessary plant for a pattern-shop. The fifth bay may be called the boiler-erecting shop, and is about 30 feet high to underside of roof principals. This shop is equipped with four fixed riveters, situated under a brick riveting tower 60 feet high, which on the side next to the shop is open for the full width of 45 feet, the wall above being carried by a box girder 33 feet from the floor. There are also portable riveting machines slung from cranes (one being worked by compressed air), which are chiefly used in riveting the ends and flues into boilers. In this operation every rivet on the front of Lancashire boilers, inclusive of those connecting the flues to the end plates, is here closed by machinery; and throughout the works a preference is given to machine riveting on account of its greater reliability than hand work. In this shop is also a range of pipes from the receiver of the air-compressor, fitted with taps at intervals for the attachment of pneumatic caulking tools. The whole of the plant is arranged as far as practicable to save labour in handling the materials. The boiler-shell plates, for example, are unloaded direct from the railway trucks in the shell-shop, and are handled by electric travellers throughout all the operations of planing, bending, drilling, &c., until the rings are finished ready to be rolled across to the riveting tower. After being hoisted up in the tower by power-driven crabs for the purpose of riveting, they are lowered down into the shell-shop, where the travelling cranes again take charge of them during the various stages the boiler has to go through before it is completed for the hydraulic test. This test takes place close to the railway truck, upon which the boiler is then lifted for proceeding to its destination. The boiler-erecting shop is the last of the bays devoted to boiler-work, the two adjoining bays, 45 and 20 feet span respectively, being occupied with building electric travelling cranes. The wider bay is about 32 feet high to underside of roof principals; while the narrower one is about the same height, but is divided into two storeys, with the side next to the wider shop left open. The wider bay is served with two electric three-motor overhead travelling cranes, and on the floor are placed the heavier machine tools used in this branch of the business, so that they have the advantage of these cranes for moving the work on and off them. Amongst these machines may be mentioned a Niles planer, with four tool-boxes, to take 6 feet square by 16 feet long; a Pond 6-feet radial drill; a Kendall & Gent horizontal boring machine, and Niles 6-feet boring and turning machine, and a number of sliding, surfacing, and screw-cutting lathes from 12-inch to 16-inch centres, in which the most noticeable feature is the large diameter of the cones and gearing in the headstock, this being obtained by stepping down the bed under the headstock. In this shop is also situated the crane-testing pit, about 36 feet long by 20 feet deep, over which every crane turned out by the firm is erected and tested under actual working conditions with the full load, the pit being of sufficient capacity to allow a 120-ton crane to be erected and tested over it. The ground floor of the narrower bay is occupied with a number of screw-cutting lathes up to 10 centres, Bullard boring and turning mills, milling, gear-cutting, slotting, drilling, screwing, grinding machines, &c., also capstan and turret lathes of English and American manufacture. The upper floor is occupied by armature winders, &c., and is equipped with a number of machines, including lathes, electric motors, &c. It will be noticed that the three bays where the heaviest weights have to be handled are well equipped with electric three-motor overhead travelling cranes, there being two or three in each of those bays. It is considered that the output of a shop depends quite as much upon the efficiency of its lifting appliances as upon the actual speed of the machines doing the work. There are at present about 260 hands employed at these works.

## MESSRS. J. E. H. ANDREW & CO., LTD., STOCKPORT GAS-ENGINE WORKS, REDDISH.

These works, which are of considerable size, are situate adjoining the London and North-Western Railway Station, Reddish, ten minutes' walk from Reddish Great Central Railway Station, and a quarter of an hour's walk from Heaton Chapel Station, London and North-Western Railway. The works are devoted solely to the manufacture of "Stockport" gas-engines, in sizes from 1 horse-power to 250 horse-power. The factory is driven by gas-engines worked from fuel-gas made on the premises. Messrs. Andrew make a specialty of large power gas-engines to be worked by producer-gas, and several sizes can be seen in course of production. The works contain many examples of the most modern tools and labour-saving appliances, including electric travelling cranes. They are lighted throughout by the electric light, and are capable of turning out about 16 gas-engines per week.

## MESSRS. ASHTON BROS. & CO., LTD., CARRFIELD AND THROSTLE BANK MILLS, HYDE.

These mills have been built at various times from the beginning of the present century. The older mills are driven by compound engines with steam at 80 lbs. pressure, and the new mills by a pair of compound engines of 1000 horse-power of the Corliss type, and two sets of triple-expansion engines each 500 horse-power. Throstle Bank Mill is driven by two sets of triple-expansion engines of 1000 horse-power and 500 horse-power. All the modern engines are for rope-driving, working at 150 lbs. pressure, and all made by Mr. Goodfellow of Hyde. The boilers at Carrfield Mills are 30 feet by 8 feet, made by Messrs. J. Adamson and Co. of Hyde. Those at Throstle Bank Mills are 30 feet by 8 feet 6 inches, made by Mr. Thos. Beeley of Hyde Junction Works. All the boilers are working at 150 lbs. pressure. The mills are almost entirely lit with electricity. There are three 1000-light dynamos at Carrfield Mills coupled direct to Messrs. Willans & Robinson's engines. At Throstle Bank Mills the dynamos are driven from the main engines, and are capable of lighting 1250 incandescent lamps, thus making a total of over 4000 lamps. The dynamos, engines, and wiring have been supplied and fixed by Messrs. J. H. Holmes & Co., of Newcastle-on-Tyne.

There is spinning and preparing machinery for supplying the 3200 looms, the total number of workpeople employed being about 2200. The average output of calico is over 900,000 yards per week, weighing nearly 100 tons.

## MESSRS. BEYER, PEACOCK & CO., GORTON FOUNDRY.

These works are situated alongside the Great Central Railway at Gorton. They were founded in 1854, and at the present time occupy nearly 22 acres. The general offices are handsome and lofty, and the drawing office is exceptionally capacious, well fitted and well lighted. Electric light is employed throughout this department in conjunction with gas, both of which can be used at once or separately. Electric light is also used in the pattern-making shop and other workshops. Connected with the drawing office are photographic and model rooms, including a tracing-room, in which girls are exclusively employed. The works are arranged in three main avenues running north and south, the shops standing west to east across each avenue, with a large block of buildings to the south. In the northern end of the western avenue are tin and gas-fitting shops, and a brass-foundry containing twelve furnaces. The next building is the iron-foundry, a lofty structure in two bays, each originally 143 feet long, but recently extended to a length of 264 feet to embrace a steel-foundry. In each of the older bays there is an overhead rope-driven traveller of 10 tons, and in one of them an overhead 5-ton crane also; while in one of the extended bays a 15-ton electrically-driven traveller has been erected. Besides these there are various jib-cranes ranging in power from 1 to 3 tons, worked by hydraulic pressure, which command the entire area of the iron-foundry. Leading from this department is the tool-shop, also in two bays, originally 143 feet long, but recently extended to 264 feet. This contains some exceptionally large and heavy tools, including a planing machine, designed to take the largest locomotive frames that are made. The extensions are each provided with electrically-driven 3-ton walking cranes. The tool-erecting shop adjoining is in one bay, and is provided with a powerful 25-ton overhead travelling crane. A room forming a wing to this bay is set apart for keeping templates of all kinds, and beyond it is a house containing a 50-ton Wicksteed machine for testing the materials used. The frame machine-shop consists of four bays 143 feet long, the first two being provided with machinery for preparing the frames for the subsequent fitting, which is performed in the other two. Among the machines in this shop are slotting machines fitted with three heads, and making a 12-inch stroke, and hydraulic machines for riveting. Next is a shop for locomotive erection, in a single bay 386 feet long. Lifting power is provided by one 25-ton and one 40-ton overhead traveller, which span the entire width of the section. In the central avenue the shops are 163 feet long, and the western erecting-shop being coupled to the central one by a length of 80 feet, the two powerful travelling cranes are thus enabled to serve the whole 386 feet length of erecting-shop commanded by them. The floor of this shop is laid with six different gauges of railway, besides an 18-inch gauge line which runs through all the shops and yards. The four bays which follow comprise the machine-shop, two being devoted mainly to wheels, and two to cranks, &c. The travelling and jib cranes are driven by ropes. All the wheels and crank-pins are forced on by hydraulic power. The cylinder-shops in two bays are succeeded by an erecting-shop for tramway engines, and the latter by shops for wheel cutting and grinding. The pattern-making shop and pattern stores at the northern end of the eastern avenue are on two floors, and are lighted by electricity from the adjoining electric-lighting house. The bays in the eastern avenue are all 123 feet long, and the twelve following the pattern department are occupied with the general smithy and boiler-erecting and machine shops, in which hydraulic riveters are extensively used, and most of the flanging is also done by hydraulic power. The southern block of buildings comprises an extensive forge, wheel-making, and case-hardening shops, in three bays 164 feet long. In the wheel-making shop there are nine steam-hammers ranging up to 10 tons. The west section of the southern block, comprising three bays, is given up to the fitting and erection of tenders, tanks, &c: here hydraulic and steam riveters are almost exclusively used. Two separate buildings about 270 feet long, provided with an overhead traveller, are used for painting, packing, stores, &c. A new and complete installation of the most modern electrical plant, consisting of dynamos, high-speed steam-engines, and powerful steam-boilers of the locomotive type, is in course of completion for supplying electricity for the more extended lighting of the workshops, but more especially for driving, from one central station, the heavier machine tools throughout the works, it being intended to gradually supersede, as far as possible, the present mode of driving the machinery through the medium of long shafting, propelled by numerous wall engines located in the various bays. Compressed air is also being utilised for lifting light loads throughout the shops, and for driving caulking tools and other similar machines. In addition to locomotives, all kinds of tools required by locomotive and ordnance builders are manufactured here. Amongst the locomotives designed and constructed by the firm may be mentioned the large engines for the New South Wales Government lines and the Mersey Tunnel Railway, for both of which unusual power is required; in the latter case the gradients are from 1 in 27 to 1 in 30, up which a load of 150 tons has to be hauled. About 2000 men are employed at the works, and from 150 to 200 engines can be turned out in a year.

The steel foundry and plant may be regarded as a model installation for the purpose they have to fulfil—viz., the supply of the firm's ever-increasing requirements in the finest qualities of steel castings and special ingot metal. The ironwork roof and ends of the foundry carry as much glazing as possible, and give a very light interior. The design of melting furnace carried out (5-ton acid Siemens) combines the most recent improvements in open-hearth construction, and both valve pit and charging platform are unusually roomy. A special type of double-beat pot valve is used for the gas reversing, and has shown itself to be absolutely gas-tight, a quality which cannot be claimed for the butterfly valve, in common use elsewhere with the smaller Siemens furnaces. The core-drying and annealing stoves are gas fired, and work very economically. The latter is of an underground type, and the roof, which is at floor level, can be removed in segments for easy filling and emptying of the stove. The gas-producers, which have been brought as near to the furnaces as possible, are of the well-known Dawson water-bottom type, and are worked by high-pressure steam from a Cochrane's tubular boiler placed close to the coal stage. There is a special siding for the gas-producers, another for the side building, which covers the furnace platform, sand bins, and core stoves, and a siding goes into the foundry itself. Electricity is used for the lighting throughout. In each of the older bays there is an overhead rope-driven traveller of 10 tons, and in one bay there are two other cranes of 5 tons and 15 tons respectively, also placed overhead, while in one of the extended bays a 15-ton electrically-driven traveller has been erected. Besides these there are various jib cranes hydraulically worked, and they are so fixed that one with the other they command the entire place. These jib cranes vary in power from 1 to 3 tons.

### MESSRS. CRAVEN BROTHERS, LTD., OSBORNE STREET, OFF ROCHDALE ROAD.

The Vauxhall Ironworks of this Company are situated on the main tram route to Queen's Park, Harpurhey, from the end of High Street, Market Street; about 1¼ miles. The works occupy three acres and are covered with workshops and foundries all well equipped with machine tools, electric and rope-driven travelling cranes. The heaviest description of machine tools and overhead travelling cranes, driven electrically and driven by ropes, are made, and the works employ 800 men and boys.

### MESSRS. SMITH & COVENTRY, LTD., GRESLEY IRONWORKS, ORDSALL LANE, SALFORD.

These works are situated in Ordsall Lane, Salford. The firm is engaged in building all descriptions of milling machines, bevel-wheel shaping machines, turning and boring mills, capstan lathes, brass lathes, side planers, in addition to the regular run of machine tools, patent tool-holders, twist drills, gauges, milling cutters, &c.

## MESSRS. HICK, HARGREAVES, & CO., LTD., SOHO IRONWORKS, BOLTON.

The Soho Works were erected in 1832 as a general engineering establishment, the earlier products being stationary steam-engines, boilers, mill-gearing, hydraulic machinery, water-wheels, marine engines, and locomotives. Of the last a large number were made here for the Liverpool and Manchester and other earlier railways. The firm were the first to introduce the Corliss engine into this country, about the year 1865, and they have been closely identified with it ever since. Over 1300 of these engines have been built of all sizes, from 40 horse-power up to 10,000 horse-power, of all types, simple, compound, triple expansion, and for all working pressures up to 200 lbs. per square inch. Great attention has been given to the details of these engines, in order to ensure the highest economy and utmost regularity of speed under highly varying loads. Under favourable conditions the consumption of water or steam is now well under 12 lbs. per I.H.P. per hour, corresponding with 1¼ lbs. of coal of good quality per I.H.P. per hour. Steel boilers were first made at the Soho Works in 1863. An entirely new boiler-making plant is now being put down, and when this is in full operation the productive capacity will be increased to about 200 boilers per annum. The boilers are mostly of the Lancashire type, but several hundreds of loco type boilers for torpedo boats have been made; some of these loco boilers being amongst the largest in existence; the most recent examples having each 2400 square feet of heating surface, and whilst weighing only 16 tons, have given 1750 horse-power each on the trial trip. Mill-gearing in all its branches forms a large department of the works, some exceptionally large fly-wheels for rope-driving having been made. For instance, a rope fly-wheel 32 feet in diameter, grooved for 56 ropes, and weighing 128 tons. This was for a cotton-mill in India to transmit 3200 I.H.P. Turbines and hydraulic machinery generally are also largely manufactured. The works have been largely extended from time to time to suit the growing requirements of the trade, and they now cover 7 acres, and give employment to 1000 men. There is the usual subdivision of the work into the departments, some of which are very extensive. Alterations are always in progress, a large proportion of the plant having been renewed in the last few years. As far as possible, standardising is carried out, and many of the machines are of a special character to suit the work. All the shops are thoroughly well served by travelling-cranes, mostly driven by endless cotton ropes, but three of the more recent cranes are driven electrically. The total number of travelling-cranes in the works is 19, varying from 5 to 50 tons capacity. Some of the leading tools are of large dimensions, namely, a lathe 4–6 in. centres, 14 in. spindle, bed 50 feet long. A combined side-planer and slotter to plane 24 feet long by twelve feet high. A slotting machine with a 4–6 in. stroke. A pit planer to plane an object 20 feet by 10 feet square. A plant for turning rope fly-wheels, capable of dealing simultaneously with 4 wheels, each 32 feet in diameter, grooved for 40 ropes, as many as 30 cutting tools being sometimes in use simultaneously on one wheel. Hydraulic riveter with an 8-feet gap. The boiler works are at present in a transition state, as they are being entirely rebuilt and fitted with new plant throughout. There is an electrical department where the current for operating the cranes and for the lighting is generated. The motive power consists of 5 Lancashire boilers, 7 feet in diameter by 30 feet long, and 7 engines indicating collectively about 500 horse-power.

## MESSRS. HULSE & CO., LTD., CALDER STREET, REGENT ROAD, SALFORD.

The business of Messrs. Hulse & Co. (Limited) was orginally founded in the year 1852 by the late Mr. J. S. Hulse on his secession from the firm of Messrs. Joseph Whitworth & Co., after a connection of seventeen years. On his retirement in 1881 the business devolved upon Mr. W. W. Hulse, who carried the works on until his decease in March 1897, and was then succeeded by his son, Mr. J. W. Hulse, who died in April 1898, when the business was formed into a private limited company under the style of Hulse & Co., Limited, with Mr. Henry Bates as managing director. The business has steadily increased, and the works have been from time to time enlarged until they now occupy a floor area of over 10,000 square yards. There are five large erecting-shops, which are all served with 25 to 30 ton patent overhead travelling cranes, specially designed by the Company for engineers' workshop use, and arranged to embrace almost the entire width and length of each building. These erecting-shops have roofs glazed throughout their area, and are consequently very light. In addition to the machine and erecting shops there are machine galleries devoted to milling, cutter, gauge-making, &c., and other light work. A few years ago the adjacent works and business of Mr. Thomas Gadd, established in the year 1847 for the manufacture of machinery for calico printers, bleachers, dyers and finishers, steam-engines and cranes, were acquired, and now form a not unimportant part of the Company's business. Some of the largest and heaviest machine tools ever constructed have emanated from the Ordsal Works, notably horizontal and vertical planing machines up to 130 tons weight, twin screw lathes for turning marine cranks, propeller shafts, gun forgings, &c., up to 100 feet in length and weighing over 150 tons; special machines for the machining of armour plates, including very powerful planing machines with tables propelled by twin screws, and large drilling and tapping machines, and also complete plants for the manufacture of ordnance of all descriptions, form a specialty of the Company's productions. Particular attention is also devoted to large machine tools for marine engineering work of all desciptions, including cylinder-boring machines to bore up to 12 feet diameter, vertical lathes in sizes from 5 to 20 and 30 feet diameter, large milling machines, both vertical and horizontal, and also special tools for "Belleville" and other types of water-tube boilers. In addition, the Company make other special tools too numerous to mention here, and also the usual other general engineering tools, viz., lathes, planing, slotting, drilling machines, &c. Very many of the tools recently constructed, both of the heavy and also the smaller classes, have been arranged to be driven direct by electric motors, in some cases by constant speed, and in other cases by variable speed motors.

### MESSRS. ASA LEES & CO., LTD., SOHO IRONWORKS, OLDHAM.

This firm was founded about a century ago at Holt's Mill, Lees, and removed to Oldham in 1816. Mr. Samuel Lees, the founder, established the first foundry in the Oldham district. In 1843 the firm began the working of textile machinery, for which it has now become noted all over the world. At the present time Mr. Robert Taylor and Mr. Henry Lawton are the managing directors. The works are fitted with a great many labour-saving tools, a considerable number of which have been designed and made on the premises, the machine parts being made in duplicate and finished in a superior style. The making of textile machinery involves a great number of trades and processes, and to enumerate all of them would take up great space; but the most interesting part of the works to members of the Iron and Steel Institute is no doubt the large new foundry which has just commenced working, though it is not yet fully equipped. The floor space in this foundry for moulding is 381 feet by 156 feet, with an equal space for storing and dressing castings, softening and annealing, and for storing moulding boxes and plate patterns. When fully at work, it will have four large cupolas, which will be served with air-blast by two three-cylinder blowing engines. There are four electric lifts and one 5-ton electric travelling-crane already installed, and others will be added. Two hydraulic lifts and two 5-ton hydraulic cranes are in preparation, and there are besides a considerable number of hand and air cranes at work. The whole of the driving is electric, as well as the lighting, the electricity being generated by two dynamos driven by two of Messrs. Willans & Robinson's three-crank engines. Plate and machine moulding is largely in use, the plant including hand, hydraulic, and pneumatic machines, and also several hundred "plates." In the various departments for preparing the parts for building their machines, the firm have many interesting automatic machines, including a large number of English, American, and German manufacture, besides many of their own make. The firm have their own wood sawing-mill fitted up with the most modern log-frame saws, circular saws, and other woodworking machinery and appliances, including a patent automatic saw-sharpening machine of their own invention.

## MANCHESTER CORPORATION GASWORKS.

The Corporation possess four extensive gas stations, Gaythorn, Rochdale Road, Bradford Road, and Droylesden, the value of the land, buildings, and apparatus being respectively £252,879, £302,510, £656,595, and £27,276. Gaythorn station (reached from the Royal Exchange by Alexandra Park tramcars to Gaythorn City Road) stands on nearly nine acres, and has two retort houses with a daily productive capacity of 1,600,000 and 2,900,000 cubic feet respectively. The plant comprises one large rectangular horizontal condenser, three sets of twin rotary exhausters, eighteen scrubbers, three sets of purifiers, three station meters, and seven treble-lift gas-holders, with a total storage capacity of 6,000,000 cubic feet. Rochdale Road station (reached by tramcar from corner of High Street and Market Street, by Queen's Park) stands on over nine acres, and has three retort houses capable of producing daily 6,500,000 cubic feet of gas. The plant comprises one large rectangular horizontal condenser, two pipe coolers in water-tanks, and one Eclipse water-tube condenser, five Anderson's exhausters, two sets of scrubbers, one set of eight purifiers, five station meters, and five treble-lift gas-holders, with a total storage capacity of 5,000,000 cubic feet. Bradford Road station (reached by tramcar from Lever Street, Piccadilly, for Beswick) covers an area of over 53 acres, and has two retort houses with a total capacity of 8,000,000 cubic feet daily. The plant comprises three Morris & Cutter's water-tube condensers and one Eclipse condenser, two sets of twin rotary exhausters and engines combined, four Livesey washers, two Kirkham & Hulett's rotary washer-scrubbers, and one Clapham & Laycock's washer-scrubber, twenty-two purifiers, eight additional purifiers for the carburetted water-gas plant, four station meters, and four treble-lift holders with a joint capacity of 6,800,000 cubic feet, and a new treble-lift gas-holder, 250 feet in diameter, with a capacity of 7,000,000 cubic feet. The carburetted water-gas plant consists of four sets of Humphrey & Glasgow's producing apparatus, each of a daily capacity of 750,000 cubic feet. Droylesden station (four miles out of the city) stands on over four acres, and has one retort house with a manufacturing capacity of 500,000 cubic feet daily. There are one double-lift gas-holder and one treble-lift Gadd & Mason holder with a total storage capacity of 600,000 cubic feet. There is also an experimental plant for ammoniacal liquor purification and a sulphur recovery plant. A general summary shows that the total capital of the Corporation Gasworks is £2,050,027. The productive capacity of the works is 22,500,000 cubic feet daily; the storage capacity 25,000,000 cubic feet; the annual coal consumption 430,000 tons; the greatest daily consumption of gas 25,500,000 cubic feet; and the length of mains 786 miles.

## THE MANCHESTER CORPORATION ABATTOIRS.

The Abattoirs and Carcase Market situated in Water Street was opened in 1872, and is considered one of the finest in England. Though so recently extended as 1895, the accommodation is in full use and further additions are contemplated. The site was selected as being the most convenient for the trade, being within easy distance of the Salford Cattle Market. The buildings comprise a lofty carcase market, which fronts two sides of the site and contains 4058 square yards; a veal market containing 573 square yards; 46 slaughter-houses with lairage accommodation in direct communication; a special slaughter-house and lair for pigs and blood, gut, fat, and tripe houses. Lifting machinery is provided for each slaughter-house, and runner-rails connect the slaughter-houses with the market and also with the chill rooms adjoining.

## MANCHESTER CORPORATION FOREIGN ANIMALS WHARF, OLD TRAFFORD.

The Foreign Animals Wharf is situated on the south side of the Manchester Ship Canal, adjoining the Mode Wheel dry docks. Accommodation is provided for 1000 head of cattle, and the proposed extension will provide accommodation for 2000 more. The site covers an area of over twelve acres. The lairs are substantial brick buildings, divided into compartments, each capable of holding 50 cattle. The cooling-room is placed opposite the slaughter-houses, and is capable of holding 500 sides. There are three chill-rooms, each capable of chilling 174 sides at a time. The boiler-house contains three Lancashire boilers, and the engine-house, the engine, compressor, and circulating pump for the refrigerating machinery, the duplex pumps and accumulator for the hydraulic hoists, two 50 horse-power pumping engines for lifting the sewage of the wharf, two 50 horse-power engines, and two dynamos for electric lighting.

## MANCHESTER CORPORATION COLD STORES.

As an adjunct to the extensive markets of the Manchester Corporation, cold air stores for the preservation of perishable goods were completed in 1895. The stores are constructed to accommodate 120,000 sheep, and are made up as follows:—In the basement, 20,000 sheep or other goods; in the six chill-rooms on the ground floor, about 25,000 sheep, or 1200 sides of beef or other goods. On the first, second, and third floors, about 25,000 sheep on each floor. The rooms in the basement are 10 feet high, on the ground floor 13 feet, and on the first, second, and third floors 9 feet each. The roadways through the building have a clear head-room of 17 feet and a clear width of 20 feet. The buildings are completely equipped with all machinery, electric plant, lifts, elevators, and all other conveniences necessary for every trade requirement.

## MANCHESTER CORPORATION HYDRAULIC POWER SUPPLY PUMPING STATION.

The Hydraulic Pumping Station is situated in Gloucester Street, close to the Oxford Road Railway Station. The mains are kept charged by means of six sets of powerful pumping engines, each capable of delivering 230 gallons of power water per minute. Steam is generated in five large boilers. The reservoir of power consists of two large accumulators, loaded to a maximum pressure of 1120 lbs. per square inch. The power water is maintained in the mains at a pressure of 1000 lbs. per square inch, and is available day and night within the area of supply all the year round. The system of supply has been in operation for nearly four years, and upwards of 15½ miles of mains are now laid, from which supplies are given to over 311 premises with 1174 cranes, motors, hoists, presses, and other machines. Extensions are being proceeded with, and a pumping station in Pott Street Ancoats, is now complete.

## MANCHESTER MUNICIPAL TECHNICAL SCHOOL.

The New Municipal Technical School in Whitworth Street and Sackville Street, now in course of erection by the Corporation, is built upon a site given by the legatees of the late Sir Joseph Whitworth, Bart., which includes land (formerly known as Rifle Street) added by the Corporation, in all covering an area of nearly 6600 square yards, and having frontages to Whitworth Street, Sackville Street, and Granby Row. The building has now been in process of erection since July 26, 1895, when Alderman Hoy, the chairman of the Technical Instruction Committee, turned the first earth on the site, and will be opened in 1900. Amongst other benefactions in aid of the building and equipment fund of the School, is that given by the guarantors of the Manchester Royal Jubilee Exhibition of 1887, which amounts to nearly £14,000, and a further sum of £5000 given by Sir Joseph Whitworth's legatees. The building, which is from the designs of Messrs. Spalding & Cross, architects, of London, is in the style of the French Renaissance of Francis I., freely treated, and will be a notable addition to Manchester architecture. It is being erected in Accrington brick and in terra-cotta of an unusually pleasing tint and bold design. The main entrance, which is treated in grey Dalbeattie granite and terra-cotta, is in Sackville Street, and is a specially fine feature of the main façade. The estimated cost of the building, including equipment, but exclusive of the land, is upwards of £130,000. From the ground floor plan the general arrangement of the building on each floor can readily be seen. With the object of securing the effective lighting, all the rooms are placed in the four blocks which form the frontages of the building, and the corridors, which give ready and immediate access to each of them, are lit from the large internal area, which is divided by the large halls devoted to the museum, the great examination and assembly room, and the chemical laboratory. The basement floor is devoted to workshops and laboratories for spinning, weaving, mechanical and electrical engineering, joinery, and plumbing. On the ground floor are placed the museum, the administrative offices, laboratories for physics, lecture-rooms for spinning and weaving, joinery, and other textile workshops. On the first floor will be the scientific and technical library, the reading-room, the lecture-rooms for mathematics, physics, and engineering, workshops and drawing-room for sanitary engineering, and the large examination hall. The second floor is devoted to rooms for machine construction, and drawing and building construction; to subjects pertaining to women's industries; to domestic economy; to advanced commercial teaching; to letterpress and lithographic printing, and to the chemical museum. The third floor is entirely set apart for chemistry in its application to the various chemical industries, whilst the fourth floor is given up to industrial art, to further accommodation for the chemical industries, and to the gymnasium. Provision is made for an astronomical and meteorological observatory at the extreme north-east corner of the building. The lighting of the building will be by electricity, and the motive power for driving the various machines and appliances will also be electrical. Special consideration has been given to the subject of ventilation and heating, which will be by the Plenum system, and to the sanitary arrangements of the building, and the fitting and equipment will be made in all respects complete and efficient for the purposes of technical training in the various industries of this great manufacturing district. The number of students enrolled in the schools of the Technical Instruction Committee is upwards of 4000.

## MANCHESTER CREMATORIUM, CHORLTON-CUM-HARDY.

This Crematorium is situated alongside the Manchester Southern Cemetery on the Barlow Moor Road, and is a mile from the Chorlton-cum-Hardy and Alexandra Park Railway stations, and four miles from the Manchester Town Hall. It was built in 1892, and consists of a hall or chapel, and a separate contiguous chamber containing the furnace. Columbaria for the reception of the urns and the memorial tablets are provided in the arched recesses on the inside and outside of the principal walls of the building. The hall is about 50 feet long by 25 feet wide, and of proportionate height. In the centre of the wall opposite to the principal entrance is placed the aperture leading to the furnace, which in the separate space occupies the basement and ground floor. A vestry or record room, and a retiring room, lavatories, &c., are situated at the back of the hall, which is flanked on either side by open-arched colonnades raised above the level of the ground, protecting the columbaria in the outside wall. Dignity is given to the main entrance to the hall by means of a lofty arched porch, from which steps connect on either side to the outer colonnades and columbaria. Draught is supplied to the furnace by a chimney hidden in a tower, which gives the building the appearance of a church. It is constructed throughout in terra-cotta, and the style of architecture resembles that of some of the oldest churches in Lombardy and Venice. The general arrangement and details of the furnace are from the plans of the late Mr. Henry Simon, who personally superintended its erection. It is so constructed that the raw fuel does not come in contact with the body; the coffin is noiselessly introduced by invisible machinery. Coke or Welsh anthracite coal is used for the production of the gas, and the cremation is absolutely smokeless. The time of cremation of each body is about seventy-five minutes on an average.

## MESSRS. WILLIAM MUIR & CO., LTD., BRITANNIA WORKS, SHERBOURNE STREET, MANCHESTER.

The works, which were established in 1842, cover 1½ acres of land, having a total floor space of 138,000 square feet, and are situated and fronting on Sherbourne Street, Strangeways. On the ground floor are situated the pattern-shop, foundry, smithy, and hardening room, also the erecting and machine shops for heavy machinery; the milling and profiling department is also on this floor. The first floor is occupied by the general offices, drawing offices, stores, and machine shops for light and medium work. The second floor contains erecting and machine shops for the lighter classes of work, also the screw-making department and wheel-cutting department; the latter is fitted with the latest and most improved machinery for cutting all classes of wheel teeth, &c. On this floor is also a commodious stockroom, where a large stock of machine tools are always kept on hand ready for immediate delivery. On the third floor is the cutter-making room, fitted with special tools for making patent and ordinary milling cutters of latest approved design. The fourth, fifth, sixth, seventh, and eighth floors are storerooms for patterns, &c. The whole of the works is furnished with lifts and power-driven travelling cranes, which run the whole length of the various shops, and those on the upper floors communicate with the floors below, thus affording every facility for dealing with the work in progress. The machine tools throughout the works, with one or two exceptions, are of their own manufacture. The number of workmen employed is about 400.

### MESSRS. JOHN MUSGRAVE & SONS, LTD., GLOBE IRONWORKS, BOLTON.

A large and extensive engineering and boiler works, occupying an area of over eight acres of land entirely covered with buildings, established in 1839 by Mr. John Musgrave in conjunction with his eldest son, the late Alderman Joseph Musgrave. These works are devoted to engine-work, boiler-work, and mill gearing, and comprise large pattern-shops, moulding-shops, tool-shops, forge and smiths' shops, extensive boiler-works, and everything fitted up in the latest approved style for turning out work of the best description. In the different departments are large travelling cranes, suitable for the class of work to be dealt with, the tools being up to date, and arranged for getting out the work as quickly as possible consistent with first-class workmanship. These works have also special arrangements for the design and manufacture of large engines up to 15,000 horse-power and boilers up to 260 lbs. pressure per square inch, special attention being devoted to large engines for textile purposes and electric installations. Several large electric engines for different Corporations are now in course of construction at the works, the motive power for the electric installation being supplied by quick-speed engines of the type made by the firm. A large number of engines, &c., are sent abroad from these works every year. The firm is a private limited company, with Mr. Walter M. Musgrave as chairman and governing director, and stands to-day foremost amongst the representatives of the engineering industry.

## MESSRS. FRANK PEARN & CO., LTD.

This firm was established by Mr. Frank Pearn in the year 1870. He was joined in 1872 by his brother, Mr. Sinclair Pearn, and in 1880 by Mr. Thomas Addyman, and carried on as a partnership concern until the year 1894, when for family reasons it was made a private limited company with a capital of £60,000. The firm are makers of pumping and hydraulic machinery, and have made a world-wide reputation for this class of machinery. The works are situated in Thomas Street, West Gorton, and stand on about two acres of land. They consist of general offices, light and heavy turning-shops, machine-shop, pattern-shop, smithy, stores, &c. &c. This firm have executed many important contracts for waterworks, collieries, steelworks, &c. &c., and are contractors to the Home, Indian, and Colonial Governments, on the Admiralty list, and count amongst their clients most of the important firms at home and abroad.

## MESSRS. THOMAS ROBINSON & SON, LTD., MACHINE WORKS, ROCHDALE.

These works are situated close to the Lancashire and Yorkshire Railway, cover an area of seven acres, and employ 1200 men. Lying nearest to the railway are the sawmill and joinery works, where almost every kind of woodwork is manufactured direct from the log.

The timber in the log is first sawn in a large horizontal double-saw frame, with two saws having a horizontal reciprocating motion; they are driven at a high speed from a double-throw crank, whose centres are opposite, so that the motion of the one saw balances that of the other. The saws cut in both directions of their stroke, so that the feed of timber is continuous. Alongside is a vertical deal-cutting saw frame, arranged to work with a number of saws at once for sawing up flitches and deals. There are also various kinds of self-feeding circular saws; also planing machines, mortising and tenoning machines, &c. In addition to joinery, this department is largely devoted to the manufacture of flour-milling machinery, principally flour-dressing machines, such as semolina purifiers, sieves, bran dusters, &c., which follow the work of the roller-mills in the conversion of grain into flour.

The machine works are separated from the wood department by a street, across which runs a branch line of rails connecting with the railway. Adjoining the street are the general offices, drawing offices, pattern-shop, and foundries for iron and brass casting. Parallel to these buildings are large stores, the smithy, and the dressing-shop for castings. Alongside the latter runs a spacious yard, over the whole length of which works an overhead steam travelling-crane; here are stored the machine castings previous to their entry into the fitting-shops, which are on the other side of the yard. The works are so arranged that the raw material enters by the main line, and is discharged from the waggons direct at the foundry and smithy, from which, during the course of manufacture, it passes in direct circulation to the fitting-shops and packing department. The iron foundry is a building 317 feet long by 94 wide, built in two bays. A line of columns passes down the centre, supporting the roof and crane road. Three overhead steam travelling-cranes traverse the whole length of the building, each capable of lifting a load of ten tons. A number of machines are at work for moulding pulleys and wheels from plate patterns. The smithy is a similar building to the foundry, being lofty and spacious. It is 150 feet long by 45 feet wide, containing fifteen fires, and is fitted with steam-hammers, forging machines, and tools for special work in cutter-making and stamping forgings. The lower end of the fitting-shop is devoted to the construction of wood-working machinery, and the upper end to roller-mills for flour-milling and to steam-engines. The total length of the fitting-shop is 537 feet, and its width 103 feet. In addition to many special turning, grooving, and milling machines, there is a balancing apparatus, by means of which pulleys and cutter-blocks are accurately balanced for the speed they are intended to run at. An overhead travelling-crane, driven by rope, works over the engine fitting-shop, and is capable of lifting 15 tons. The machinery in this department is driven by a horizontal compound tandem engine of 40 horse-power, having an ordinary slide-valve, with an arrangement whereby the cut-off is regulated by the governor according to the load.

## SALFORD CORPORATION GASWORKS.

The Salford Corporation owns four gasworks—(1) Bloom Street, (2) Regent Road, (3) Liverpool Street, and (4) Albion Street, and supplies gas to the borough of Salford and Eccles, and five townships having a total area of 41 square miles and an estimated population of 300,000. The total amount of coal and cannel carbonised at all the works in the year ended 31st March last was 135,372 tons. The Bloom Street Works, which is capable of carbonising 88 tons of coal per day, is old-fashioned, and is not used for gas-making in the summer months. The Regent Road Works and the Liverpool Street and Albion Street Works are situated on either side of the London and North-Western Railway to Liverpool, and are connected by a footbridge. They were commenced in 1858, and cover an area of 12⅓ acres. These works are at present capable of carbonising about 650 tons of coal per twenty-four hours. At the Regent Road Works there are two retort houses, containing together 212 through retorts, capable of carbonising about 240 tons of coal per day. In the larger of these two houses the work of charging and drawing the retorts is effected by hydraulic machinery. The coal for use in this house passes direct from railway trucks into coal-breakers underneath, where it is broken to a convenient size. It is then elevated and conveyed to the charging machines by conveyors. The hydraulic power is obtained by means of a pair of high-pressure horizontal engines, with cylinders 12 inches diameter by 15 inches stroke, driving two differential ram pumps, each ram 6½ and 4½ inches diameter. The coal-breakers and conveyors are driven by two high-pressure horizontal engines, with cylinders 12 inches diameter and 18 inches stroke. There are two pairs of horizontal reciprocating gas exhausters, each pair capable of passing 80,000 cubic feet of gas per hour, driven by high-pressure steam-engines, with cylinders 9 inches diameter and 20 inches stroke. There are horizontal condensers, two Livesey washers, and three tower scrubbers 50 feet high and 12 feet diameter. The purifiers are six in number, 30 feet by 30 feet; their lids are lifted with screws. There are two telescopic gas-holders; one 100 feet diameter, with two lifts each 24 feet high, having a total capacity of 400,000 cubic feet, and the other 150 feet diameter, with four lifts each 30 feet high, having a total capacity of 2,000,000 cubic feet. At the Liverpool Street Works there is a retort house containing 192 retorts, 20 feet long by 22 inches wide and 16 inches high, heated by regenerative furnaces, and capable of carbonising about 270 tons of coal per day. The coal for these retorts is supplied in railway trucks, which are lifted by two 20-ton hydraulic waggon-hoists on to elevated railways over the coal stores. There are two pairs of differential ram pumps, each ram being 3⅜ and 2½ inches diameter, driven by high-pressure horizontal steam-engines, with cylinders 12 inches diameter and 18 inches stroke. There are two pairs of rotary gas exhausters. Each pair is driven by a high-pressure steam-engine, with cylinders 16 inches diameter by 22 inches stroke, and is capable of passing 200,000 cubic feet of gas per hour. There are atmospheric and water-tube condensers of the vertical type, four tower scrubbers 12 feet diameter and 60 feet high, and two rotary washers. The purifiers are six in number, 24 feet by 24 feet; their lids are lifted by hydraulic rams. The ammoniacal liquor produced at all the works is converted into sulphate of ammonia by means of a Feldman sulphate apparatus. The water required for cooling the gas, quenching coke, &c., is obtained from an artesian well. The boring is 500 feet deep, and varies from 26½ to 15 inches in diameter. The pump is 12 inches diameter by 36 inches stroke, and is driven through helical gearing by a horizontal steam-engine, having a single cylinder 12 inches diameter by 16 inches stroke. The well yields about 10,000 gallons of water per hour. There are two telescopic gas-holders; one 150 feet diameter, with three lifts each 40 feet high, the other 150 feet diameter, with four lifts each 30 feet high. The total capacity of each holder is 2,000,000 cubic feet. At the Albion Street Works there is a retort house designed to contain four benches of inclined retorts, but at present only two benches containing 56 through retorts each are erected. These retorts are built at an angle of 32°, and are charged with coal from the upper end by gravity. The coal falls from railway trucks into a coal-breaker underground, and after being broken is lifted by an elevator into large hoppers placed above the retort bench. A small hopper, which travels on rails in front of the retort bench, conveys the coal from the large hopper to the retorts as required. The coal-breaker and elevator are driven by a 14 horse-power Otto gas-engine. About 140 tons of coal per day is at present carbonised in this house. The gas manufactured at the Albion Street Works is purified, measured, and stored at the Liverpool Street Works.

## THE SEMET-SOLVAY COKE-OVENS AT BRACKLEY COLLIERY.

This installation, which is the property of the Bridgewater Trustees, is situated at Brackley Colliery, near Little Hulton. It consists of twenty-five Semet-Solvay coke-ovens, using washed fuel from an Elliot washer, the slack being ground prior to charging into the ovens. The ovens are provided with scrubbing and condensing apparatus for the collection of tar, ammonia liquor, and light oil. The liquor is treated to produce sulphate of ammonia. The coke is discharged by a ram on to a coke car, on which the coke is spread while it is being watered. It is discharged into the railway waggons for transport.

## MESSRS. VAUGHAN & SON, LTD., ROYAL IRONWORKS, WEST GORTON, MANCHESTER.

Manufacturers of three-motor overhead electric travellers, which type of crane they claim to be one of the first to introduce into this country. The works are situated within easy access of Manchester, and there is always a number of electric travellers in varying stages of progress to be seen. At work in their erecting-shop is a 20-ton three-motor overhead electric traveller, embodying all the latest improvements, and the outcome of their lengthened experience in the design and construction of this type of crane. They have an order—amongst many others—that will be the largest electric traveller made in this country, viz., one to lift 125 tons, span 50 feet, for Sir W. G. Armstrong, Whitworth & Company, Limited.

# OBITUARY.

**Howard Bowser** died on September 8, 1899, at the age of seventy-five years. He went to Scotland about the year 1847, where he entered into partnership with the late Mr. D. Y. Stewart, the inventor of a method of casting iron pipes vertically. The development of this trade, of which Messrs. Stewart & Bowser are considered the pioneers, has grown to such an extent that it now forms one of the most important of the industries of Glasgow. Since Mr. Stewart's death in 1882, the capacity of the works, in regard both to quantity and efficiency, has been greatly increased under Mr. Bowser's supervision, and at the time of his death he was maturing a scheme of extensive improvements in the electric power of the works. He was well known among gas and water engineers throughout the world, and was greatly respected. He was elected a member of the Iron and Steel Institute in 1873.

**William Franklin Durfee** died in the State Hospital, Middletown, New York, on November 12, 1899, after a short but very severe illness. Born at New Bedford, Massachusetts, in 1833, he graduated at Harvard University in 1853, after which he became an engineer and architect in his native town, and for five years served as municipal surveyor. In 1861 he was elected a member of the State Legislature, and did valuable work as secretary of the Military Committee. In 1862 he went to Lake Superior to report on the suitability of the iron ores of that region for steel-making. He erected experimental works at Wyandotte, Michigan, where steel ingots were produced. At these works he equipped the first chemical laboratory built as an adjunct to steelworks in the United States. Since that time he had the management of various works, and successfully introduced the regenerative furnace at several places. The first Bessemer steel rails made in the United States were rolled at the North Chicago Rolling Mill on May 24, 1865, from ingots made at the Wyandotte works under Mr. Durfee's management. He was the author of numerous works on scientific subjects, and was the owner of a valuable library which he bequeathed to the American Society of Mechanical Engineers, of which society he was vice-president in 1896–98. He was elected a member of the Iron and Steel Institute in 1875.

**William Orme Foster** died on September 29, 1899, at the advanced age of eighty-five years. He was the head of the firm of Messrs. John Bradley & Company, and held a very high position among the ironmasters of South Staffordshire. The firm's principal works are at Stourbridge, where they were established more than a century ago, but they also had other works in different parts of the Staffordshire and Shropshire ironmaking districts. Mr. Foster was one of the Members for the old Parliamentary division of South Staffordshire from 1857 to 1868. He was also High Sheriff for the County of Wexford in 1876, and for Shropshire in 1883. He was a generous supporter of all public works of importance in the districts with which he was associated, and one of his benefactions took the form of a church, vicarage, schools, and schoolhouse for the parish of Wollaston, where many of his workpeople resided. At his death the gross value of his estate was £1,000,000. He was an original member of the Iron and Steel Institute.

**John Frew** died on August 26, 1899, at the age of fifty years. Born at Ardeer, Ayrshire, he held for some time a position of trust under the Ardeer Ironworks Company, after which he was appointed by a Glasgow syndicate furnace manager at their works in America, a position which he held for several years. On his return to Scotland he entered the Langloan Ironworks as blast-furnace manager, and whilst at these works he invented his blast-furnace pyrometer, which has been largely adopted. About ten years ago he entered the service of the Carron Company as blast-furnace manager, a position held by him until 1892, when he was appointed general manager. Through ill-health he was compelled, a short time before his death, to resign this position, and a movement was in progress for marking the value of his services to the Company, and the high esteem in which he was held, by the presentation of an illuminated address. The silver casket which was to contain it was received at the works on the day of his death. A large sum was subscribed for the purpose, and his untimely death occasioned deep regret among all with whom he had been connected. The works of the Carron Company were largely extended during his general managership, and a further extensive addition was in progress at the time of his death. He was president of the Larbert Horticultural Society, and was elected a member of the Iron and Steel Institute in 1886.

William Kennedy died on May 20, 1899, at his residence, near Glasgow, at the age of sixty-two years. He was a native of the Upper Ward of Lanarkshire, and came to Glasgow in 1853, where he entered the employment of the firm of Messrs. P. & R. Fleming, with whom he remained for three years. He subsequently went to Messrs. Henry Field & Son, ironmongers, of Glasgow, where he devoted himself to the improvement of the manufacture of paraffin oil lamps, which at that time were coming into use; and he did much to bring this into favour, both in Scotland and in Ireland. In 1861 he became connected with the manufacture of paraffin oil at the West Calder Company's works, with which firm he remained for seven years. On severing his connection with this Company he co-operated with Mr. Fraser, of Glasgow, in purchasing the Oakbank Oil Works, near Calder, of which he was general manager until 1877, when he took an active part in the formation of the Broxburn Oil Company, of which he was for some years managing director. He was also secretary of the Scottish Mineral Oil Association until 1876, and was subsequently elected president. In all the important negotiations carried on between the American and Scotch oil industries, with a view to reconciling conflicting interests, he took a leading part. He was also a director of the Niddrie and Benhar Coal Company, Limited, and of the Glenboig Union Fireclay Company, Limited. He was a County Councillor for Linlithgowshire. He was elected a member of the Iron and Steel Institute in 1890.

John Needham died at his residence, Highfield, Eccles, on October 18, 1899. He was the head of the firm of John Needham & Sons, of Manchester; chairman of the Cheadle Park Colliery Company, Staffordshire; of George Needham, Limited, Salford; and also of the Northern Steel and Hardware Company, Limited, of Salford and Glasgow. He had a very large experience in all the branches of the machinery trade both of this country and the United States of America, and only a short time before his death paid a visit to America for the purpose of ascertaining the latest progress in machinery and plant generally. He was elected a member of the Iron and Steel Institute in 1888, the meetings of which he regularly attended. Owing to failing health he did not take an active part in the Manchester meeting, but was represented on the Executive Committee by his son, Mr. C. T. Needham.

HENRY SIMON died at his residence, Didsbury, near Manchester, on July 22, 1899. He was the son of a Government official of Brieg, in Silesia, and was born in 1835. In consequence of the revolution the family was compelled to leave Brieg, and they settled for a time at Zürich, where Mr. Henry Simon attended the cantonal public school. At the age of nineteen he entered the University of Breslau, but subsequently returned to Switzerland to study engineering at the Federal Technical College, Zürich, where he graduated in engineering in 1859. He then went to Berlin to fulfil his military service, first in the artillery and then in the guards. On the completion of his military service he commenced practice as an engineer in Magdeburg, in the establishment of Messrs. Röhrig, Röhrig & König. He then went to Russia, and later to France, and finally settled in Manchester, where he established himself as a consulting engineer. He spent the greater part of 1867 at the Paris International Exhibition, when he became a life-member of the Société des Ingénieurs Civils de France. He took a lively and practical interest in local affairs, and took an active part in all educational, social, and municipal movements for the improvement of the city of his adoption, where he was most highly esteemed. Amongst his numerous benefactions to educational work was the endowment of a professorship in German Literature at Owens College, and he was a large contributor to the fund for the establishment of the new laboratories at that College. His genius was many-sided, and in his professional career he attained numerous and important successes. In regard to flour-milling machinery it is said that the mills constructed on the "Simon system" are of sufficient capacity to grind annually four times the average production of the United Kingdom. In the session of 1881–82 Mr. Simon read a paper before the Institution of Civil Engineers describing his system of flour-milling. His more important achievement was, however, his improvement of the Carvès coke ovens, to which he devoted the closest attention. Since the introduction on a large scale of the Simon-Carvès coke ovens at the collieries of Messrs. Pease & Partners in the county of Durham many years ago, great progress has been made in the perfection of the system, which is now in operation in the principal coking districts throughout Europe. The enormous saving in the utilisation of the waste products in coking is well known, and is computed at several millions sterling annually. The installation of these ovens, which embodies all the latest improvements in the system, was visited by the members of the Iron and Steel Institute at the recent meeting in Manchester, when an excursion was made to the Wharncliffe-Silkstone Collieries for this purpose a few days after the death of Mr. Simon, a fact which was the subject of deep regret on the part of the members. He was a member of the Institution of Civil Engineers, of the Institution of Mechanical Engineers, and of various kindred institutions on the Continent, in addition to other scientific societies in this country. He was elected a member of the Iron and Steel Institute in 1874, and contributed to the Proceedings important papers in 1877 on Chaudron's method of shaft-sinking, in 1880 on the utilisation of by-products in the manufacture of coke, and in 1885 on the development of the Simon-Carvès coking process.

EUSTACE WIGZELL died on October 2, 1899. He was formerly engineer to the Russian Government Works at Ekaterinburg, in the province of Perm. He subsequently joined Mr. Joseph Pollit of Sowerby Bridge as a general engineer under the style of Timothy Bates & Co. On the firm being converted into a limited liability company Mr. Wigzell became managing director, which position he held at the time of his death. He was a member of the Institution of Mechanical Engineers, and was elected a member of the Iron and Steel Institute in 1881.

# ADDITIONS TO THE LIBRARY

## DURING THE SECOND HALF OF 1899.

| Title. | By whom Presented. |
|---|---|
| "The Petroleum Industry of Roumania." (Pamphlet.) By D. A. Sutherland. London. 1899. Reprinted from the *Petroleum Review*, April 1 and 15, 1899. | The Author. |
| "Die Verdichtung der Röstgase in Kotterbach." (Pamphlet.) By Dr. H. Wedding. Berlin. 1899. | The Author. |
| "Report of the Seventh Meeting of the Australasian Association for the Advancement of Science, held at Sydney, 1898." Sydney. 1899. | The Association. |
| "Souvenir Album of the Visit of the Iron and Steel Institute to Stockholm, August 1898." London. 1899. | Purchased. |
| "Manganese in the Open-Hearth (Acid) Process." By F. A. Matthewman. Glasgow. 1899. (Pamphlet.) | The Author. |
| "The Application of Mechanics to Engineering Practice." By Archibald Barr. London. 1899. | The Secretary of the Institution of Civil Engineers. |
| "Statistics of the American Iron Trade for the Year 1898." By J. M. Swank. Washington. 1899. (Pamphlet.) | The Author. |
| "Report of the Year ending 31st December 1898, as Presented by the State Mining Engineer to the Government of the South African Republic." Pretoria. 1899. | The State Mining Engineer. |
| "Bulletin of the National Export Exhibition." Vol. i. No. 11. | F. Lynwood Garrison. |
| *Journal of the Canadian Mining Institute.* Vol. ii. 1899. Containing Paper on "Swedish Iron Metallurgy." By James Douglas. | The Author. |

| Title. | By whom Presented. |
|---|---|
| “The Lake Superior Iron Ore Mines and their Influence on the Production of Iron and Steel.” By Jeremiah Head and A. P. Head. London. 1899. | A. P. Head. |
| “Mines and Quarries: General Report and Statistics for 1898.” Part II. Labour. London. 1899. | The Under-Secretary of State. |
| “Seventh Supplement to the Register of the British Corporation for the Survey and Registry of Shipping: Additions and Corrections.” September 1899. | The Corporation. |
| ‘Report upon the Manufacture of Iron and Steel in India.” By R. H. Mahon. Simla. 1899. | The Author. |
| “Everett Coke-Oven Gas Plant at Boston, Massachusetts.” (Pamphlet.) By F. Schniewind. (*The Progressive Age*, Vol. xvii. Nos. 16 and 17, 1899.) | The Author. |
| “Production of Illuminating Gas and Coke in By-Product Ovens.” By H. O. Hofman. 1898. (Pamphlet.) | Dr. F. Schniewind. |
| “Kommerskollegii Underdåniga Berättelse för År 1898.” Stockholm. 1899. (Pamphlet.) | R. Åkerman. |
| “Bericht über die aus Anlass des Fünfzigjährigen Bestandes des Oesterr. Ingenieur- und Architekten Vereins.” Vienna. 1899. | The Society. |
| “Calendar of the Working Men’s College. London.” Forty-fifth Year, 1898–99. | The College. |
| “Mining and General Telegraphic Code.” By Bedford M‘Neill. London. 1898. And “Terminal Index for use with the Code.” | The Author. |
| “Report of the Tests of Metals during the Fiscal Year ending June 30, 1898.” | The War Department, Washington. |
| “Light Tramway and Railway Journal.” Vol. i. No. 2. September 1899. | The Editor. |
| “Journal of the American Foundrymen’s Association.” Vol. vi. No. 36. June 1899. | T. D. West. |
| “Die Fortschritte in der magnetischen Aufbereitung der Erze.” By Dr. H. Wedding. | The Author. |
| “Mines and Quarries: General Report and Statistics for 1898.” Part iii. London. 1899. | The Under-Secretary of State. |
| “Guide to Queensland.” By C. S. Rutlidge, F.R.G.S. London. 1899. | The Agent-General for Queensland. |
| “The Lives of Engineers.” Vols. i. ii. iii. London. 1861. | H. Chapman. |

| Title. | By whom Presented. |
|---|---|
| "Life of the Marquis of Worcester." London. 1865. | H. Chapman. |
| "Life and Labours of Mr. Thomas Brassey." London. 1872. | H. Chapman. |
| "Life of Richard Trevithick." London. 1872. | H. Chapman. |
| "Illustrated Catalogue of Wire Ropes." | T. W. Scott. |
| "Le Mois Scientifique et Industriel." Paris. 1899. | The Editor. |
| "Fowler's Mechanical Engineer's Pocket-Book for 1900." Edited by W. H. Fowler. Manchester. 1899. | The Editor. |
| "The International Catalogue of Scientific Literature." Edited by John Shirley. Brisbane. 1899. | The Agent-General for Queensland. |
| "Dr. Johann Friedrich Wedding." By H. Wedding. Berlin. 1899. | The Author. |
| "Note sur les Gisements de Minerais de Fer." By P. Bayard. Paris. 1899. | The Author. |
| "Bye-laws and List of Members of the International Association for Testing Materials." Zürich. 1899. | The Association. |
| "Annuaire Statistique de la Belgique, 1899." Brussels. 1899. | Ministère de l'Interieur. |

## INSTITUTIONS.

The Publications of the Institute are exchanged for those of the following Institutions :—

### LONDON.

Board of Trade.
British Fire Prevention Committee.
Chemical Society.
City and Guilds Institute.
Geological Society.
H.M. Patent Office.
Imperial Institute.
Institution of Civil Engineers.
Institution of Electrical Engineers.
Institution of Mechanical Engineers.
Institution of Mining and Metallurgy.

Institution of Naval Architects.
Royal Artillery Institution.
Royal Institute of British Architects.
Royal Institution.
Royal Society.
Royal Statistical Society.
Royal United Service Institution
Society of Arts.
Society of Chemical Industry.
Society of Engineers.
University College.

## PROVINCIAL.

Cleveland Institution of Engineers.
Engineering Society (Leeds).
Hull and District Institution of Engineers.
Institution of Engineers and Shipbuilders in Scotland.
Liverpool Engineering Society.
Manchester Association of Engineers.
Manchester Geological Society.
Mason College (Birmingham).
Merchant Venturers' Technical College (Bristol).
Mining Institute of Scotland.
North-East Coast Institution of Engineers.
North of England Institute of Mining and Mechanical Engineers.
Royal Dublin Society.
Sheffield Technical School.
South Staffordshire Institute of Iron and Steel Works Managers.
South Staffordshire Ironmasters' Association.
South Wales Institute of Engineers.
University College of South Wales.
West of Scotland Iron and Steel Institute.

## COLONIAL AND FOREIGN.

### Colonial.

Canadian Institute.
Canadian Mining Institute.
Canadian Society of Civil Engineers.
Department of Mines, Sydney.
Department of Mines, Melbourne.
Geological Survey of Canada.
Geological Survey of India.
Geological Survey of New South Wales.
Mining Society of Nova Scotia.
Royal Society of New South Wales.

### United States.

Alabama Industrial and Scientific Society.
American Association for the Advancement of Science.
American Institute of Mining Engineers.
American Iron and Steel Association.
American Society of Civil Engineers.
American Society of Mechanical Engineers.
Department of Labour.
Engineers' Society of Western Pennsylvania.
Franklin Institute.
New York Academy of Sciences.
Ordnance Office, War Department.
School of Mines, Columbia College, New York.
Smithsonian Institute.
United States Geological Survey.

### Austria.

K.k. geologische Reichsanstalt.
Oesterr. Ingenieur- und Architekten-Verein.

### Belgium.

Association des Ingénieurs sortis de l'Ecole des Mines de Liége.
Ministère de l'Interieur.

### France.

Comité des Forges.
"Revue Maritime." Ministère de la Marine.
Société d'Encouragement pour l'Industrie Nationale.
Société de l'Industrie Minérale.
Société des Anciens Élèves des Écoles Nationales d'Arts et Métiers.
Société des Ingénieurs Civils.
Société Scientifique Industrielle de Marseille.

### Denmark.

Tekniske Foreningen.

### Germany.

Königliche Bergakademie in Freiberg.
Königliche Technische Versuchsanstalt.
Verein Deutscher Eisenhüttenleute. (Journal "Stahl und Eisen.")
Verein Deutscher Ingenieure.

### Italy.

Reale Accademia dei Lincei.

### Sweden.

Jernkontoret.

## JOURNALS.

The following periodicals have been presented by their respective Editors:—

### UNITED KINGDOM.

“Coal and Iron.”
“Commerce.”
“Contract Journal.”
“Colliery Guardian.”
“Electrician.”
“Electrical Engineer.”
“Engineer.”
“Engineer and Iron Trades’ Advertiser.”
“Engineering.”
“Engineers’ Gazette.”
“Hardwareman.”
“Hardware Trade Journal.”
“Industries and Iron.”
“Invention.”
“Iron and Steel Trades’ Journal.”
“Iron and Coal Trades’ Review.”
“Ironmonger.”
“Ironmongery.”
“Iron Trade Circular.”
“Machinery Market.”
“Marine Engineer.”
“Mechanical Engineer.”
“Phillips’ Monthly Register.”
“Plumber and Decorator.”
“Practical Engineer.”
“Railway Engineer.”
“Railway World.”
“Science and Art of Mining.”
“Shipping World.”
“Statist.”
“Steamship.”
“The London Technical Education Gazette.”
“Tool and Machinery Register.”

### COLONIAL AND FOREIGN.

#### Colonial.

“Canadian Mining Review.”
“Indian and Eastern Engineer.”
“Indian Engineering.”

## United States.

"Age of Steel."
"American Journal of Science."
"American Manufacturer."
"Bradstreet's."
"Cassier's Magazine."
"Engineering and Mining Journal."
"Engineering Magazine."
"Engineering News."
"Iron Age."
"Iron Trade Review."
"Letter of the Anthracite Coal Operators' Association."
"Metallographist."
"Mines and Minerals."
"Railroad Gazette."
"Report of Proceedings of the Master Car Builders' Association."
"Tin and Terne."

## Austria.

"Allgemeine bergmännische Zeitschrift."
"Oesterr. Zeitschrift für Berg- und Hüttenwesen."

## Belgium.

"Bulletin de l'Union des Charbonnages de Liége."
"Moniteur des Intérêts Matériels."
"Revue Universelle des Mines."

## France.

"Annales des Mines."
"L'Echo des Mines."
"Le Génie Civil."
"Le Mois Scientifique et Industriel."
"Portefeuille Économique."

## Germany.

"Annalen für Gewerbe und Bauwesen."
"Chemiker Zeitung."
"Glückauf."
"Verein Deutscher Eisen und Stahl Industrieller."
"Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate."
"Zeitschrift für praktische Geologie."
"Zeitschrift für Werkzeugmaschinen und Werkzeuge."

**Italy.**

"L'Industria."
"Rassegna Mineraria."

**Spain.**

"Revista Minera."

**Sweden.**

"Teknisk Tidskrift."

# SECTION II.

# *NOTES ON THE PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.*

## CONTENTS.

PAGE
Iron Ores . . . . . . 306
Refractory Materials . . . 337
Fuel . . . . . . . . 339
Production of Pig Iron . . 398
Production of Malleable Iron . 417
Forge and Mill Machinery . 420
Production of Steel . . . 426
Further Treatment of Iron and Steel . . . . . . 445
Physical Properties . . . 451
Chemical Properties . . . 473
Chemical Analysis . . . 480
Statistics . . . . . . 494
Bibliography . . . . . 530

In the preparation of these Notes the Editor has been assisted by E. J. Ball, Ph.D., H. G. Graves, Assoc. R.S.M., and G. Kamensky, Assoc. R.S.M.

# IRON ORES.

## *CONTENTS.*

| | | PAGE |
|---|---|---|
| I. | Occurrence and Composition | 306 |
| II. | Iron Ore Mining | 326 |
| III. | Mechanical Preparation | 332 |
| IV. | Metallurgical Preparation | 334 |

## I.—*OCCURRENCE AND COMPOSITION.*

**The Age of Iron Ore Veins.**—H. Höfer,* in discussing the question as to the determination of the age of mineral veins, divides them into fissures produced by some change within the enclosing rock, such as shrinkage, and those produced by some external cause. In the first case they are of the same age as their enclosing rocks, but it is much more difficult to determine the age of those of the other kind. While, as a general rule, when a fissure is found not to pass from one rock into the one above it, it may be assumed that its age lies between those of the two rocks; yet this is not always the case, as the author shows. If the upper rock is of a tougher character than the other, it may not fissure to the same extent, and a force which could cause a fissure to form in the more fragile rock below it, might be unable to cause that fissure to pass into the more flexible rock above it. Much may be learned by comparing the strike of fissures in one set of rocks with that of other rocks; by noticing the way they are thrown by faults whose age can be ascertained; and by observing the relation such veins may bear to eruptive rocks the age of which is known. The author gives instances, and shows in connection with the ore veins of the Erzgebirge that the Joachimthal veins were formed chiefly in Eocene or Oligocene times, and to a slight extent, too, in the Miocene period, thus showing that the formation of fissure veins of this class may extend over a lengthened period.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 157–160, and 169–171; two illustrations.

It is possible, the author thinks, that the deposition of the mineral contents followed in many instances immediately upon the formation of the fissure, or at least the commencement of this filling up of the fissure took place then. This would especially apply to the fissures formed within eruptive rocks on cooling, and at a time when hot water, and perhaps gases, were escaping. He instances the case of a hot-spring near Dux in Bohemia, which it became necessary to investigate owing to the flooding of adjacent brown coal workings. The sides of the fissure were found to be coated with heavy spar, and the deposition was still in progress. This spring must have been active for a very lengthened period indeed, and yet the fissure was not nearly filled, thus showing the great length of time which it may take to fill up a fissure with mineral constituents.

**Iron Ore Deposits.**—Léon Demaret * read a paper before the Association of Engineers of Liége on iron ore deposits. He reviewed the world's principal deposits, paying special attention to those of industrial importance or of geological interest.

The principal German and Austrian iron ore deposits are also described by W. Petersson.†

**Titaniferous Magnetites.**—The division of magnetic ores into non-titaniferous and titaniferous, according to J. F. Kemp,‡ in a review of the latter class, agrees with their geological relations and their utilisation. At present the titaniferous ores are scarcely used, and the production of the non-titaniferous ores has decreased during recent years on account of the great production of the Lake Superior ores. The only large American magnetite deposits in work are the Cornwall banks in Pennsylvania. Generally speaking, the magnetites vary widely in their geological relations, except the massive titaniferous varieties which are almost always associated with rocks of the gabbro family. The Brazilian deposits and the ores at Alnö in Sweden form exceptions. In most cases they form large irregular masses in intrusive igneous rock, and are formed by segregation before or during cooling. Sometimes the mineral impregnates the rock. The quantity is so large, and the iron made from these ores is such, that probably it will not be long before they are utilised. Mineralogically the ores are ilmenite, $FeO,TiO_2$, and titaniferous magnetite of varying composition, which cannot be enriched by magnetic concentration. Phosphorus and sulphur are generally absent, but vanadium, chromium, nickel, and cobalt are nearly always present.

---

* *Bulletin de l'Association des Ingénieurs Sortis de l'Ecole de Liége*, vol. xxiii. pp. 63-65.

† *Jernkontorets Annaler*, vol. liv. pp. 1-97.

‡ *School of Mines Quarterly*, vol. xx. pp. 323-356.

The author then proceeds to describe in some detail the various deposits of the world, dealing especially with those in Quebec and Ontario in Canada, Colorado, Minnesota, New Jersey, New York, North Carolina, Rhode Island, Virginia, and Wyoming in the United States; Brazil in South America; Finland, Norway, Russia, and Sweden in Europe; and in New Zealand.

**Iron Ore in Kent.**—One of the sinkings near Dover has passed through a bed of oolitic iron ore, about twelve feet in thickness, at a depth of about six hundred feet from the surface, and it is stated that the same seam has been struck in a boring at Ropersole, about twelve miles distant. The ore consists of granules of limonite embedded in a matrix which varies in amount at different parts of the layer.*

Analyses of the ore made by E. Riley and R. H. Harland, and published by the Colliery Company, show that the contents range between:—

| | Unwashed Ore. | Washed Ore. |
|---|---|---|
| Iron | 32·08 to 42·14 | 49·83 |
| Sulphur | 0·03 to 0·084 | 0·09 |
| Phosphorus | 0·38 to 0·59 | 0·50 |
| Alumina | 4·88 to 8·55 | |
| Lime | 1·99 to 9·94 | |
| Silica | 11·00 to 15·10 | |
| Manganese oxide | 0·20 to 0·40 | |

**Iron Ore in Oxfordshire.**—It is stated † that iron ore is to be extensively worked near Hook Norton in Oxfordshire, and that two kilns 70 feet in height with a steam-lift for loaded waggons have been erected for the purpose of drying the ore, to save in the cost of transport.

**Devonian Iron Ores in Moravia.**—The increasing dearth of suitable iron ores for many of the Austrian blast-furnaces renders it necessary to direct attention to the smaller deposits from which supplies of ore might be obtained. With this object in view, Franz

---

* *Ironmonger*, vol. lxxxviii. p. 119.

† *Manchester Guardian*, through *Industries and Iron*, vol. xxvii. p. 202.

Kretschmer * has made a detailed investigation of a series of iron ore deposits of economic importance in the Devonian strata of Moravia and Silesia, which even in the Middle Ages and in the present century served as the basis for an important part of the Moravian and Silesian iron trade, but now, owing to better means of communication with distant districts where ores are mined on a huge scale, are mostly lying idle. The deposits are not only of economic importance, but also of considerable geological interest. The Devonian formation of Moravia and Silesia contains, besides smaller deposits, three large well-defined series of iron ore beds, which in ascending order are as follows:—1. The ore bed of Moravian-Aussee. This is the most important from a mining point of view, and is of Lower Devonian age. 2. The second ore bed at the Pinkerberg, near Moravian-Neustadt, also occurs in the Lower Devonian, but close to the limit of the Middle Devonian. 3. Close to the contact of the Devonian strata with the culm beds there is met with a diabase dyke, accompanying which iron ores are found. These form the third series of beds. The author's memoir, which covers 96 pages, contains a detailed geological description of the various beds. He also describes at considerable length the various mines of the district, namely, the Poleitz, the Meedl, the Pinke, and the Sternberg Mines. The Meedl deposit is the richest, most productive, and most extensively worked. The largest mine at Meedl is worked by the Witkowitz Company. It raises 12,000 tons annually of magnetite and red hæmatite, and affords employment to a hundred men.

**Iron Ore in France.**—In 1896 and 1898 A. Lacroix showed that the granite mass of Quérigut afforded useful evidence regarding the theory of metamorphism. The granite has been brought to its present position by progressive dissolution of schists and limestones. It has thus been subjected to repeated and remarkable endomorphous changes, and inversely has greatly metamorphosed these sedimentary rocks. The author has also endeavoured to show that the exomorphous metamorphic changes have been largely due to emanations of volatile products brought by the eruptive rock. He now † describes a vein of magnetite in connection with the Quérigut granite which furnishes a new argument in support of his theory.

---

* *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlix. pp. 29–124.

† *Comptes Rendus de l'Academie des Sciences*, July 18, 1899.

**Iron Ore in Luxemburg and Lorraine.**—L. Hoffmann * describes the occurrence of oolitic iron ore in Luxemburg and Lorraine. This ore, which plays so important a part in the iron industry of the Continent, covers an area of sixty by eighteen miles. There are five main seams, the ore containing on an average 36 per cent. of iron, 5 to 20 per cent. of lime, 7 to 34 per cent. of silica, 2 to 10 per cent. of alumina, and 1·7 per cent. of phosphoric acid.

P. Villain † observes that the deposit of oolitic iron ore in Lorraine has been considered to show all the characteristics of a littoral deposit, the mineralisation of which was produced by thermal springs rising from the bottom of the Liassic sea. This theory has been contested, no points of emergence of such springs having so far been found. The author, however, considers the theory to be a true one for reasons which he proceeds to give. He considers that they came through fissures corresponding to faults most of which are now well known. Most authors appear to admit that these faults are posterior to the deposition of ore. It is certain that many of them have faulted the ore deposits long after the latter were formed, but it is not a certainty that some faults may not have been in existence before the ore. Indeed this is more probable. The faults of the Briey basin appear to date from Tertiary times, and their formation may have been accompanied by a return of thermal activity, giving rise to the minerals called *fer fort,* which are always found superimposed on the oolitic ores. Assuming the thermal activity to have been very variable in different places, the differences noted in the ore seams would be at once accounted for. In Lorraine the chief centre of emission both for the Liassic and Tertiary periods was situated between Audun-le-Tiche and Esch-sur-Alzette. This is accounted for by the great Audun-le-Tiche fault, which causes a throw of the beds in this region of more than a hundred yards. The Longwy basin is in part also connected with this same fault, and in part with other faults of lesser importance. That of Pontoy in Alsace-Lorraine, near the village of that name, which also causes a throw of some hundred yards, has played an equally important part in the formation of the basin. Other faults, and the ore deposits to which they have given rise, are also named. Quite recently it has been possible to study in detail the part played by the Bonvilliers fault, which has only recently been discovered, but which would appear to play a decisive rôle as regards the eastern extension of the Briey basin. At Bonvilliers this fault throws the beds some fifty yards, and has given rise to an ore deposit which, though of relatively small area, is of exceptionable richness. The chief centre of emission of the ferruginous spring was probably not far from Bonvilliers. Pulverulent iron oxide was deposited in the supernatant water, and this spread itself irregularly over the bed of the sea. The directions taken by the oxide have been mapped out during the past three years by means of numerous boreholes. These have shown that the deepest depressions of the bed correspond with the line of maximum richness of the deposit. The author draws attention to other points which favour this theory.

---

* *Glückauf,* vol. xxxv. pp. 640–645.

† *Echo des Mines et de la Métallurgie,* 1899, p. 5527.

O. Lang * observes that the views that are held as to the origin of the iron ores of Lorraine are still of a very divided character, some holding them to have a primary, and others a secondary character. The author passes in review the opinions expressed by various writers.

**Iron Ore in Siegen.**—An interesting contribution to the knowledge of ore deposits is furnished by G. Koehler,† who has published the results of a careful study of the dislocations in the spathic iron ore veins of the Siegen district.

**The Pazzano Iron Ore Deposits.**—The iron ore deposits of Pazzano, Italy, were worked in very ancient times,‡ and mention is made of them in documents of the year 1094. They were worked at intervals down to 1883, when work finally ceased. According to Cortese § the ore is found between Devonian slates and Jurassic limestone. It is a hydroxide of very variable appearance, being at times of an earthy structure, and at others a brown hæmatite. According to Czyskoroski, the composition of the ore is shown by the following partial analyses :—

| Iron. | Sulphur. | Phosphorus. | Silica. |
|---|---|---|---|
| 53·54 to 58·43 | traces to 0·20 | 0·13 to 0·33 | 1·01 to 4·75. |

The deposits have been traced for a distance of 2½ miles, and the workings have shown them to be generally of considerable extent.

**Iron Ore in the Ural Mountains.**—H. B. C. Nitze || describes the iron ores of the Northern, Central, and Southern Ural.

---

* *Stahl und Eisen*, vol. xix. pp. 714–718.

† *Berg- und Hüttenmännische Zeitung*, vol. lviii. pp. 217-219.

‡ *Rassegna Mineraria*, vol. xi. p. 200.

§ *Descrizione Geologica della Calabria*, Rome, 1895.

*Journal of the Franklin Institute*, vol. cxlvii. pp. 442–447.

The Northern Ural district is the least developed. Some small deposits on the western slopes produce 45 to 50 per cent. ores. Farther in the interior of the mountain chain are large ore bodies, such as the Kutinski and the Jubrischski mines, which produce rich specular ores, containing 60 to 65 per cent. of metallic iron, at a cost of 2s. 8d. a ton at the mines. The district of Bogoslovsk produces 50 to 60 per cent. ores, worth 3s. 9d. at the mines.

The ore deposits of the Middle or Central Ural are more developed, and are concentrated within a smaller area. The two principal producers are the Blagodat mines at Kouchwa and the Wyssokaja mines at Tagil, both on the line of the Perm-Ekatherineburg railroad.

The Southern Ural is the richest in ores. The two principal localities are the Bakalski mines, in the district of Slatoust, and the Magnetnaia mines, in the region of the Ural Cossacks.

A brief description of these different mines and their geological formation is given. The paper contains little in connection with the deposits that is not given in H. Bauerman's paper.*

**Iron Ore Deposits near Kertsch.**—M. Glasenapp † describes the ore deposits in the neighbourhood of the town of Kertsch in the Tauris peninsula, Russia. These deposits, he observes, have acquired greater importance the more they have been worked, as the quality of the ore mined has undergone improvement. The ore is stated by Zeidler to be brown hæmatite of an oolitic character. The seams rich in manganese have smaller seams of manganese ore running through them. The ore occurs in large quantities, and the deposits are well situated for mining. Placed on board ship in the harbour at Kertsch, the first cost of the ore would not exceed one kopeck the pood. Up to now the cheapness has been considered to be more than counterbalanced by the poor quality of the ore, both chemically and physically. It was poor in iron, but rich in silica and high in phosphorus. As far as low contents of iron are concerned, it has been found that this only applies to the upper layers of ore, the quality of the middle seams being better, whilst those still lower down are again of a poorer quality and more closely resemble the upper seams. The following are analytical results from the ore at different points :—

---

* *Journal of the Iron and Steel Institute*, vol. liii. pp. 134-144.

† *Chemiker Zeitung*, vol. xxiii. ; *Repertorium*, p. 217; *Rigaer Industrie Zeitung*, 1899, p. 73.

| | Upper and Lower Ore. | Middle Ore. |
|---|---|---|
| | Per Cent. | Per Cent. |
| Iron | 25 to 35 | 40 to 46 |
| Manganese | 1 to 5 | 0·3 to 3·0 |
| Silica | About 25 | 15 |
| Alumina | ? | 5 to 6 |
| Phosphorus | ? | 1 to 1·5 |

On picking the ore about 20 per cent. of lump ore is obtained, and 80 per cent. of fine ore cemented together by ferruginous clay. The Krivoi Rog ore, on the other hand, often contains a fine amorphous ore powder which disturbs regular blast-furnace practice. Zeidler recommends that the Kertsch ore should be mixed with Krivoi Rog ore for smelting purposes.

**Manganese Ores in South Russia.**—According to Zeidler,* there are two deposits of manganese ore in South Russia that are utilised in the iron industry. The first of these is the deposit of pyrolusite to the west of the town of Nicopol. This deposit is regular in character and of Tertiary age. Its extent is not yet known. It consists of pyrolusite granules of different size enclosed in an earthy material poorer in manganese. From this it has to be separated either by sifting or by washing. By these means the raw material yields from 30 to 40 per cent. of marketable ore. The raw ore contains from 30 to 35 per cent. of manganese. After enrichment the composition is as follows :—

| | Washed Ore, 1st quality. | Sifted Ore, 2nd quality. |
|---|---|---|
| | Per Cent. | Per Cent. |
| Manganese | 50 to 51 | 42 to 46 |
| Silica | 8·00 | 15·00 |
| Phosphorus | 0·25 | 0·2 to 0·3 |
| Iron | ... | 2 to 5 |

The residue, for which no use has yet been found, still contains from 25 to 30 per cent. of manganese. In 1897 there were sold 3,330,000 poods of this Nicopol ore.

The second deposit, that of the Caucasus, belongs to the Chalk. The ore is found in a vertical seam some seven feet in thickness. The composition of the ore shows from 50 to 55 per cent. of manganese, and from 0·10 to 0·15 per cent. of phosphorus. The deposit is of very considerable extent. In 1896 there was exported from the port of Poti 8,842,000 poods of this ore, and in 1897, 11,441,000 poods. The Briansk and Dniéprovienne Ironworks of South Russia smelt chiefly ore from the Nicopol deposit. From this they produce for their own use a spiegeleisen with from 10 to 12 per cent. of manganese. At the Hughes Works, No. 7 blast-furnace, which is smaller than the others, produces regularly spiegeleisen with from 18 to 20 per cent. of manganese, and ferro-manganese with from 40 to 80 per cent.

---

* *Revue Universelle des Mines*, vol. xlvii. pp. 69–77.

The imports of ferro-manganese into Russia amounted in 1897 to 1,036,000 poods. This represents material containing from 20 to 80 per cent. of manganese. Metal with less manganese than this is classed as pig iron, and it is consequently impossible to determine the quantity of spiegeleisen which is imported into Russia. The author then proceeds to give statistics showing the cost of production of ferro-manganese in Russia. From these he shows that the use of the Nicopol ore is most advantageous commercially for the ironworks of the Dnieper basin, while the use of ore from the Caucasus is preferable in the case of works near the Sea of Azov.

The Caucasus deposit is worked by a kind of pillar-and-stall method, a large proportion of the ore being left in the pillars. There are a large number of small mining undertakings at work on this ore deposit.

**Mercury in Russian Iron Ore.**—It is stated by Barval [*] that analyses which he has made of a brown iron ore from the Caucasus have shown that the ore contains mercury.

**Iron Ore in Spain.**—Nordal Preus [†] describes three iron ore mines called the Santa Justa, La Giralda, and Mercedes, in the Puebla de los Infantes, in the province of Seville. The deposits consist of masses of hæmatite extending over a large area and containing 60 to 65 per cent. of iron, and merely traces of phosphorus. They can be worked opencast, and are favourably situated with respect to means of communication, being five miles from the station of Peñaflor.

---

[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 286.

[†] *Revista Minera*, vol. l. pp. 440-441.

**Iron Ore in Sweden.**—J. Mauerhofer* describes visits that he has paid to a number of the mining centres of Sweden. He deals first with the ore deposits of Grängesberg and its immediate neighbourhood. The ores found near Ludvika are magnetites and red hæmatites, containing from 55 to 65 per cent. of iron, and from seven mines 29,776 tons of ore were obtained. In the immediate neighbourhood is an available waterfall power exceeding 5000 horse-power. The Grängesberg ore deposits appear to have been known for about two centuries. They extend for a distance of over three miles in length with a width of about 0·6 of a mile. Various methods of mining are in use, there being both open-cast and deep workings. The open-cast is the one chiefly employed. Magnetites with from 62 to 64 per cent. of iron are mined in this field. The ore deposits and the methods of working are described at some length. In deep workings there are three shifts in the twenty-four hours, while ten-hour shifts are employed in open-cast workings.

NAWAB SALAR JUNG BAHADUR

Electricity is very largely employed at the Grängesberg mines, water power being available for use in generating it. The author describes how this is effected.

A large quantity of the ore mined is very small, and until recently this small ore was not dealt with and was of no value. Now a magnetic separation plant is used to treat it, with a result that even from the smallest ore fines—the so-called "dust"—a product is obtained which contains from 58 to 60 per cent. of iron. From 350 tons of raw material, 200 tons of ore, 50 tons of "dust," and 100 tons of residues now result. The author gives some statistical details relating to the production of Swedish iron ore.

D. A. Louis † gives an illustrated account of the magnetic deposits of Kiirunavaara and Luossavaara, visited in 1898 by a party of members of the Iron and Steel Institute, and of the port at Svartön where the ore from Gellivare is magnetically concentrated and shipped.

**Persistency of Swedish Iron Ore Deposits.**—Professor H. Sjögren ‡ discusses the persistency of the Swedish iron ore deposits with increasing depth. The question whether there will be any change with depth is one that may be subdivided into two subordinate questions—a theoretical and a practical one—the former dealing with the change in the properties of the ore, and the latter with the maintenance of the ore at greater depths. From purely theoretical grounds it is to be assumed that the ores will show changes in the proportion of metal and in the character of the stratification. The more the problem of the genesis of ores is studied, the more complicated it is found to be. The ores are not to be regarded as the result of a single process of formation. They were not produced, for example, in a finished form by a simple process of deposition, but were subsequently subjected to changes of various kinds in form and composition. No theory hitherto proposed, whether sedimentary or eruptive, or intermediate between the two, has furnished a satisfactory explanation of the form of the ore, or of the nature of its deposition, if these properties are regarded as original. Consequently it is necessary in the explanation of the process of ore formation to assume changes which have taken place during various periods. A part of these at least took place after the ores, together with the surrounding rocks, were forced up into the steep or overturned position which is peculiar to the Swedish Archæan rocks. It is natural then to assume that circulating solutions formed the most active agent in the alteration. These solutions could, owing to their proportion of oxygen and carbonic acid, dissolve the mineral constituents and enrich or concentrate the ore in places, at the same time altering the surrounding rock. The chlorite and talc minerals so characteristic of the filling of fissures are all products of the decomposition of other silicates. It may, therefore, be assumed *a priori* that between the upper and deeper portions of an ore bed differences must exist, the upper having been subjected to a greater action of the acid water passing downwards. Clear evidence of this is afforded in the iron ore districts of Lake Superior. There ores occur in many respects like the Swedish, both the sandy ores and the self-fluxing ores; but calcareous mixed ores are not met with. The ores have been followed to a depth of 600 yards, quartzose ores being frequently found to pass, as the depth increases, into carbonates with 20 to 24 per cent. of iron. American geologists regard this low-grade carbonate as the original ore material. Oxygenated water from the surface oxidised the carbonate to limonite and magnetite, and was thus saturated with carbonic acid, which redissolved the iron carbonate, and this was again precipitated by the oxidising action of oxygenated water. Should alkalies be present in the solutions, silica would also be taken up, which, together with iron, lime, and magnesia, would form the silicates of the pyroxene, amphibole, garnet, and epidote groups, which form the gangue. The solutions can also act on the surrounding rock, especially with greenstone veins. It is, therefore, evident that because the water as the principal agent came from the surface, the action must have been greatest there, and the ores may be expected to be in the most concentrated condition. With increasing depth the ores pass into worthless carbonate. This may be observed in America. In Sweden this is not the case, because the mines are less deep, and the surrounding rock, as a rule, is unaltered. The Swedish iron mines are rarely more than 300 yards deep. Most mines have been abandoned long before such depths were attained, because the ores have either thinned out or have decreased in yield. In the Wermland iron mines the decrease in yield is specially noticeable. The output of the province fell from 85,000 tons in 1866 to 78,000 tons in 1896, and the number of mines working has fallen from 70 to 28.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 313–316, and 328–331; with numerous illustrations.

† *Engineering Magazine*, vol. xvii. pp. 632–644.

‡ *Wermländska Bergsmannaföreningens Annaler.* Filipstad, 1899, pp. 14–20.

**Iron Ore in Switzerland.**—The mineral resources of Switzerland are not considerable. Iron ore, however, occurs in large quantities.* Near Delsberg, in the Canton of Bern, pisolitic ore is met with at the base of the Tertiary beds. As the beds on the northern side of the valley have been exhausted, mining operations have to be extended to the beds below the valley at a depth of over 100 yards. The deposits are irregular in character, and the ore, consisting of rounded grains embedded in clay, is not always present in workable quantities. The Jura has been explored in all directions for iron ore, which has, however, been found only in the Mettemberg Valley and at Delsberg. In the cantons of Aargau and Solothurn oolitic iron ores of the Upper and Middle Dogger beds have been used for smelting. There are abandoned iron ore mines in the cantons of Unterwalden, Uri, and Glarus. Up to fifteen years ago a vein of manganiferous specular iron ore was worked in the canton of St. Gallen. Lack of fuel, however, rendered it necessary to abandon the mines. The Bernese Oberland is rich in iron ores, and mining was formerly actively carried on. The ore occurs in the Lauterbrunnen Valley and at Lengnau. Magnetite was found at the Wetterhorn. As wood had to be used as fuel, and as the authorities feared that the district would be deforested, the mines had to be given up. Numerous old mines that worked red hæmatite with a calcareous gangue are to be seen in the valley of the Avers, in the canton of Graubünden. An Italian company successfully carried on mining operations for some years, and that period sufficed to destroy the greater portion of the forests.

---

* *Zeitschrift für praktische Geologie*, 1899, pp. 220–224.

**Manganese Ore in Australia.**—W. M. Doherty * found scattered about at the surface over a wide area near Omybygambah, on Tweed River, a number of small nodules varying in size from a pea to a nut. Analyses of three showed—

| | | | |
|---|---|---|---|
| Gangue | 49·60 | 50·20 | 32·10 |
| $Fe_2O_3$ and $Al_2O_3$ | 11·20 | 8·70 | 14·00 |
| $MnO_2$ | 24·70 | 25·00 | 40·60 |
| $MgCO_3$ | 2·00 | 2·60 | 3·10 |
| Organic matter | 12·00 | 12·80 | 10·00 |

**Iron Ore in Canada.**—T. D. Ledyard † gives the following analysis of ore from the Belmont mine, used at the Deseronto furnace:—

| Iron. | Silica. | Phosphorus. | Sulphur. | Lime. |
|---|---|---|---|---|
| 61·29 | 6·91 | 0·003 | 0·027 | 2·82 |

Various occurrences of iron ore are reported in Canada, and a number of analyses are given.‡

**Magnetic Iron Ores in Eastern Ontario.**—F. J. Pope § gives some notes on the magnetic iron ore deposits in Eastern Ontario. They are classified under three heads—as ore bodies where the magnetite occurs in lenses or as impregnations in schistose or gneissic belts; ore bodies occurring in belts of crystalline limestone immediately at their contact with the harder gneissic and schistose members of the series; and ore bodies, titaniferous in character, occurring entirely in the anorthosites and basic gabbros. As examples of the first series, short descriptions are given of the Paxton, Seymour, and Robertsville mines; of the second, the Black Bay, Glendower, Dufferin, and Howland mines are mentioned; while Chaffey, Pine Lake, Eagle Lake and others constitute examples of the third class. Complete analyses are given of these ores. The author then turns to the chemical analysis of the ores, especially for titanium and vanadium, and discusses the occurrence of those elements, and of nickel and cobalt in magnetites. Vanadium invariably appears as a constituent of titaniferous ores, and the ratio of the oxides, $TiO_2$ to $V_2O_5$, approximates to 28 to 1. Nickel and cobalt similarly accompany the titanium, not only in the Ontario ores, but also in ores from many other districts, and it is suggested that the nickel may be the cause of the good quality of iron made from such ores. Platinum could not be found in titaniferous ores. A number of experiments were made to determine whether the ores could be freed from the titanium by magnetic separation in a Wetherill machine. With Eagle Lake and Pine Lake ore no alteration was effected, but in the case of Chaffey ore the tailings were found to be richer in titanium.

---

* *Report of the Seventh Meeting of the Australasian Association for the Advancement of Science*, vol. vii. p. 339.

† *American Manufacturer*, vol. lxv. p. 187.

‡ *Geological Survey of Canada, Annual Report*, vol. ix.

§ *Transactions of the American Institute of Mining Engineers*, October 1899.

**Iron Ore in Cape Breton.**—M. A. Macpherson* describes the magnetic iron ore deposit recently discovered over an area of two square miles near Bras d'Or Lake in Cape Breton. The rocks are of Laurentian age, and consist of granite, gneiss, and slate. Some development work has been done, and shows that very large amounts of the ore are present. An analysis gives—

| Fe. | Mn. | $SiO_2$. | P. | S. | Ti. |
|---|---|---|---|---|---|
| 58·56 | 1·98 | 5·79 | 0·019 | 0·013 | 0·95 |

**Iron Ore in British Columbia.**—According to W. C. Cronemeyer,† iron ore of very rich quality has been found in a number of places in British Columbia. Probably the best and most accessible deposits are to be found on certain islands in Barclay Sound, which is on the south-west coast of Vancouver Island, and only about fifty miles over the water from the nearest point of the State of Washington. In the Straits of Georgia, which separate Vancouver Island from the mainland of British Columbia, are Texada and Redonda Islands, which contain good deposits of iron ore. On the coast of the mainland, north of Vancouver Island, at Rivers Inlet, are also deposits of ore which has shown by analysis—

| | Per Cent. |
|---|---|
| Iron | 69·85 |
| Manganese | trace |
| Siliceous matter | 2·75 |
| Sulphur | 0·06 |
| Phosphoric acid | trace |
| Moisture | trace |

On Tzartoos Island, in Barclay Sound, where, as has been said, are the most accessible deposits, there is a mine already opened up, which has been estimated to contain about 5,000,000 tons of ore. Analyses show—

---

* *Iron and Coal Trades Review*, vol. lix. pp. 346–347.

† *Industries and Iron*, vol. xxvii. p. 130.

| | I. | II. | III. | IV. | V. | VI. |
|---|---|---|---|---|---|---|
| Iron . . . | 64·00 | 64·01 | 66·60 | 66·62 | 67·98 | 69·160 |
| Silica . . . | 7·35 | ... | 2·00 | ... | 2·67 | 1·500 |
| Alumina . . | 0·52 | ... | ... | 0·14 | ... | ... |
| Sulphur . . | 0·0054 | 0·008 | 0·02 | 0·006 | trace | trace |
| Phosphorus . | 0·0071 | 0·01 | 0·01 | 0·003 | 0·008 | 0·007 |
| Lime . . . | 3·76 | ... | 4·00 | .. | 3·000 | 0·250 |
| Manganese . | trace | ... | ... | ... | 0·250 | 0·160 |
| Magnesia . . | ... | ... | ... | ... | 1·250 | 0·120 |

**Chrome Iron Ore in Canada.**—J. T. Donald [*] describes a chrome iron ore deposit in Coleraine, Megantic county, 160 miles from Montreal, and 86 from Quebec. The ore is traceable as a belt in the serpentine over a distance of about 260 feet, and a breadth of some 60 feet. The percentage of chromium oxide is given as about 38 to 45 per cent., and it has been concentrated up to 52·6 per cent. on a Wilfley table.

**Iron Ore in Belle Isle, Newfoundland.**—It is stated that the output of ore from Belle Isle, Conception Bay, Newfoundland, now reaches 2500 tons daily. The ore is hæmatite and occurs in two beds, one 200 feet thick and a mile long, the other 300 feet thick and three miles in length. The workings are open cast, and the ore is loosened by steam-drills and dynamite.[†]

C. A. Meissner [‡] discusses prospecting for iron ore in Newfoundland and Cape Breton. Reference is made to the uniform and extensive deposits of Belle Isle which average 55 per cent. of iron. Elsewhere the features of these districts are very similar to those of the Lake Superior regions. Prospecting is therefore a matter of extreme uncertainty, and the diamond drill is the most suitable means to be employed. Whycocomagh in Cape Breton is quoted as an example of the irregular deposits. Here two veins containing magnetite, hæmatite, and specular ore were found; but though there was a strong hanging wall and the dip of the strata was persistent, there was no sign of ore in depth.

**Iron Ore in Alabama.**—In a paper read before the Alabama Industrial and Scientific Society, J. W. Castleman [§] described the brown iron ore mines recently opened up near Leeds, in Jefferson county, Alabama. The present output is about 400 tons of ore a day.

---

[*] *Journal of the Canadian Mining Institute*, vol. ii. pp. 25–27.

[†] *American Manufacturer*, vol. lxv. p. 207.

[‡] *Journal of the Canadian Mining Institute*, vol. ii. pp. 66–71.

[§] *Proceedings of the Alabama Industrial and Scientific Society*, vol. ix. pp. 13-18.

**Iron Ore in Virginia.**—C. Catlett [*] describes the iron ores of the Potsdam formation on the eastern side of the Valley of Virginia and north of Roanoke, which occur in the heavy clays and shales lying between the quartzite and the limestone. The ores are found over a distance of 150 miles, either as a more or less irregular bed or as lenticular deposits. At times they are highly manganiferous and in some places manganese replaces the iron. McCreath has given the average contents as 48·646 of iron and 0·259 per cent. of phosphorus; but the average of the ores as mined and handled is not over 42 to 43 per cent. By jigging some of the fine ore the percentage was increased to 45 or 46, but with much loss of ore. Silica occurs in combination as clay, and phosphorus near Roanoke is high, being from 0·60 to 0·90, but elsewhere is much lower, and ore can be obtained with it as low as 0·2 to 0·25. The ore is stripped and worked open cast, and in some cases there are underground workings. It has to be washed to free it from clay.

**Iron Ore in the Antilles.**—David T. Day, [†] chief of the Division of Mining Statistics of the United States Geological Survey, discusses the mineral resources of the Antilles and the Philippines. In Cuba coal does not exist, but in Porto Rico there are deposits near San Sebastian in the western part of the island. In the Philippines coal is widely distributed. Iron ore is the chief metallic product of Cuba. It occurs in the Sierra Macotra, a few miles east of Santiago. In Porto Rico there are valuable deposits north of Juncos, estimated to contain ten million tons of iron. In the Philippines iron ore exists in abundance on the islands of Luzon, Panay, and Cebu.

Some photographic illustrations and a general account of some iron ore mines, which are to be opened up near Santiago, Cuba, have appeared. [‡]

An official report made by R. P. Porter [§] deals with the recent conditions of the iron ore mines in Cuba. The mining districts are confined to the eastern end of the island, and the province of Santiago is the largest producer. Three companies at work here are the

---

[*] *Transactions of the American Institute of Mining Engineers*, February 1899.

[†] *Engineering Magazine*, vol. xvii. pp. 242–251.

[‡] *Iron Trade Review*, vol. xxxii. August 3, 1899, pp. 12–14.

[§] *Iron Age*, vol. lxiv. August 17, 1899, pp. 3–4.

Juragua, Spanish American, and Sigua companies. Between 1884 and 1897 they have produced 3,443,444 tons of ore, the first named company being accountable for 3,000,000 tons. All the ore is worked open cast. Since the war, the mines have again been worked, but there has been some difficulty in getting a sufficient number of labourers. A considerable number of ore properties are for sale in the district.

**Manganese Ore in Brazil.**—F. Greven * considers the statements which have appeared as to the deposits of manganese ore in Brazil, and gives further information as to them. The beds of ore which are found between Queluz and Marianna were mentioned, he observes, at the commencement of the present century, by V. Eschwege, but means of transport to the coast were at that time too poor to render the working of these deposits possible. This only became the case on the construction of the railway from Rio de Janeiro into the interior, which opened out the field at several places. Owing to its lack of coal Brazil itself has no use for the ore, the consequence being that only an export trade is possible. The beds enclosing the ore seams belong to what is known as the Huron series. They are mostly clay slates and mica schist, with some quartzite and crystalline limestone. The country is very hilly in parts, the highest point being 5700 feet above sea-level, and on the hillsides outcrops of ore are noticeable in numerous places.

According to a report by Ribeiro Lisboa, the ore now being mined in the vicinity of Queluz and Miguel Bournier averages from 50 to 54 per cent. of manganese, and consists chiefly of manganite, pyrolusite and psilomelane being secondary to this. The percentage of iron does not exceed 5. Some phosphoric acid is also present, and the percentage of volatile constituents is from 10 to 15. In the seams occurring in the neighbourhood of Ouro Preto along the line of the Central Railway, the ore is almost exclusively psilomelane and pyrolusite, while manganite is scarcely noticeable. The difference in the ores from the two fields is most distinct. The Queluz and Miguel Bournier ores are of a completely earthy appearance, very soft, and almost quite without metallic lustre, while the Ouro Preto ore is very lustrous and has a very compact, finely granular texture, and possesses considerable hardness. It contains about 55 to 58 per cent. of manganese, and from traces to 0·35 per cent. of phosphorus. The ore of these Ouro Preto deposits is not, however, as rich as that which occurs near the Henrique Hargreaves station. Here an ore sample was found to contain 84 per cent. of manganese peroxide, which is equivalent to 60·48 per cent. of metallic manganese. This ore is not only rich, but occurs in considerable quantities, being over 5 yards in thickness of pure ore. In the vicinity of Ouro Preto, above the main seam, which is from 3 to 4 yards in thickness, is a second seam of about similar size, which has evidently resulted by alluvial means, and for the larger part consists of rounded lumps of ore, partly loose, and in part cemented together. In the neighbouring Seramenha field only this upper seam has so far been met with, though there is but little doubt that the other will subsequently be discovered. Adjoining the manganese ore is, on all sides, brown hæmatite, with a very high percentage of iron. On the border lines the manganese ore and the iron ore are at times intimately intermingled, and numerous lumps of brown hæmatite are also found in the bed of manganese boulders itself, but they can very readily be separated by hand. The author considers that the various deposits met with in so many different places are very likely only the remnants of one large continuous deposit belonging to one and the same geological age, broken into fragments by the valley-forming action of water, and the ore consequently only remains in the form of fragments at the higher portions of the country. In any case, these ore deposits are both rich and large, and put far into the shade the deposits hitherto worked, especially those of Europe. Ribeiro Lisboa has given details as to the cost of mining and working, and these the author again enumerates. The cost of getting the ore is estimated at about 4s. 10d. per ton, and the total cost delivered in the United Kingdom, including commission, at about 38s. 3d. the cost of freight by sea alone being four times the cost of getting the ore.

---

* *Stahl und Eisen*, vol. xix. pp. 439–441.

Daniel Bellet* has published an article on the manganese mines of Brazil in which he gives a general review of the deposits in Brazil, with data of cost of mining and transport.

According to the American Consul, J. W. Furniss, † two manganese ore mines are now at work in the State of Bahia, about sixteen miles from Nazareth. The ore occurs mostly in pockets near the surface in the form of psilomelane. It is hand-picked and carried by rail.

**The Iron Ore Mines of Rar-el-Maden.**—The small port of Honaine,‡ not far from the mouth of the Tafna, on the coast of Algiers, was, up to eighteen months ago, a small harbour of shelter for fishing-boats, while at the present time it is the point of departure and lading of large ocean steamers, due to the working of iron ore deposits. A wire ropeway connects the harbour with the mines. The wire ropeway is divided into four sections, and has consequently three intermediary stations. It is about 4¾ miles in length and can convey 20 tons in the hour. The ore occurs at the surface, and is a compact deposit of considerable size. It is at present worked open-cast. The following are analyses:—

---

* *Revue Technique*, April 25, 1899.

† *American Manufacturer*, vol. lxv. p. 167.

‡ *Stahl und Eisen*, vol. xix. pp. 669–672; four illustrations.

| | Per Cent. | Per Cent. |
|---|---|---|
| $Fe_2O_3$ | 72·52 | 74·79 |
| $Mn_3O_4$ | 9·48 | 13·20 |
| $SiO_2$ | 4·32 | 1·22 |
| $Al_2O_3$ | 2·60 | 1·55 |
| CaO | 0·27 | 0·33 |
| MgO | 0·47 | 0·59 |
| $P_2O_5$ | 0·02 | 0·03 |
| S | 0·02 | 0·03 |
| Loss on ignition | 10·86 | 8·06 |

It consists of a manganiferous brown hæmatite, and contains on the average from 50 to 52 per cent. of iron, with 5 to 8 per cent. of manganese. It is intended to mine from 60,000 to 70,000 tons in the first year. From December 1898, when the first exportation took place, to July 1899, 38,000 tons of ore were exported.

These mines are also described by E. Dietz.*

**Iron Ore in Tunis.**—A. Prost † describes the iron ore deposits of the territories of the tribes of the Meknas and Nefzas in Tunis. The ores are siliceous, and can by screening easily be brought to 55 per cent. of iron. The Ras-el-Radjel ore is particularly rich in manganese, of which it contains 28·72 per cent. to 21·01 per cent. of iron. The ores are as free from phosphorus as the Bilbao ores, but the presence of arsenic has hitherto interfered with their development. The proportion of that metalloid is, however, very trifling.

**Recent Researches on Meteorites.**—Stanislas Meunier ‡ gives some details of a meteoric fall recently observed in Finland. At the beginning of March a ball of fire was seen to traverse the sky on the shore of the Baltic. After its explosion a mass fell in the sea near Borgo. The sea was frozen at the time, and the fall of the block produced a hole 9 yards in diameter in the ice. The meteorite appears to weigh nearly a ton. The stormy weather has hitherto prevented its being raised. This will be done, however, as soon as the condition of the sea will permit.

---

* *Revue Universelle des Mines*, vol. xlvii. pp. 165–172.

† *Annales des Mines*, vol. xv. pp. 538–554.

‡ *Comptes Rendus de l'Académie des Sciences*, June 3.

E. van den Brock* describes the meteorite that fell on April 13, 1896, at 7.30 A.M. at Lesves, near Fosses in Belgium. It is a stony meteorite with chondritic structure, and weighs 1360 grammes. It represents the third authentic fall observed in Belgium.

According to Gottlob E. Linck † a meteorite was seen to fall at Meuselbach, near Amt-Gehren, on May 19, 1897; it weighs 870 grammes; and has a specific gravity of 3·47. It is light grey in colour, and finely granular, with white and greenish grains and chondrules. Nickel iron, troilite, and chromite are of irregular distribution. The 7·89 per cent. of nickel iron has the following composition, agreeing with kamacite $(NiCo)Fe_6$:—

| Fe. | Ni. | Co. | Cu. | Total. |
|---|---|---|---|---|
| 85·04 | 13·61 | 1·35 | trace | 100·0 |

The portion (53·62 per cent.) of the stony matter soluble in aqua regia gave analysis I., corresponding with olivine $(Fe_2Mg_5)_2SiO_4$, and the insoluble portion (38·49 per cent.) gave the results under II., corresponding with bronzite $(FeMg_4)SiO_3$. A bulk analysis made on another portion of the meteorite gave III.; also nickel-iron 7·78.

| | $SiO_2$. | $Al_2O_3$. | FeO. | MgO. | CaO. | $Na_2O$. | $K_2O$. | FeS. |
|---|---|---|---|---|---|---|---|---|
| I. . . . . | 32·07 | 0·24 | 22·27 | 30·06 | 0·52 | 0·32 | trace | 14·52 |
| II. . . . . | 52·33 | 7·21 | 11·01 | 21·87 | 3·75 | 3·45 | trace | ... |
| III. . . . . | 40·23 | 2·85 | FeO+$Fe_2O_3$.<br>15·82 | 24·98 | 2·44 | 1·58 | trace | 5·76 |

Portion II. also contained 0·88 per cent. of chromite and Portion III. 0·35 per cent.

Under the microscope, the following (in order of predominance) were seen: Olivine, bronzite, nickel iron, troilite, colourless glass, chromite, brownish glass, and an undetermined cubic mineral. The order of formation is: Chromite, olivine and bronzite, nickel iron, troilite, cubic mineral, colourless glass.

The structure of the stone is hypidiomorphic-granular, and suggests that the minerals are primary, and that they have solidified from fusion, rather than that they are of secondary clastic origin.

---

* *Procès-Verbaux de la Société Belge de Géologie*, vol. x. pp. 63–64.

† *Annalen des k.k. naturhistorisches Hofmuseums*, vol. xiii. pp. 103–114; *Journal of the Chemical Society*, vol. lxxvi. p. 566.

W. M. Foote * describes six masses of meteoric iron weighing about 96½ lbs., and apparently forming part of the same fall, but of unknown date. They were found in Chocktaw and Sumter counties, Alabama. Analysis shows:—

| Fe. | Ni. | Co. | P. | C. | S. |
|---|---|---|---|---|---|
| 95·02 | 4·11 | 0·40 | 0·324 | 0·161 | trace. |

H. L. Ward † illustrates a new iron meteorite recently found near Murphy, Cherokee county, North Carolina. The mass has a weathered, pitted surface, and weighs just over 17 lbs. Troilites and large masses of daubreelite appear in the section, but analyses have not been made.

## II.—*IRON ORE MINING.*

**The Hodbarrow Mines.**—An illustration has appeared ‡ showing the sea-wall built about ten years ago to reclaim 35 acres of foreshore for the purpose of extending the mining operations for iron ore at the Hodbarrow mines. The wall is 3120 feet in length, and was built of concrete to a height of 33 feet above high water at neap tides, and was carried to a depth of 18 to 22 feet below the surface, and backed by a puddled bank of clay.

The results of borings have shown that there is a very large deposit of ore beyond this wall. The western limit was pretty well defined, but the whole extent of ore ground in the sea direction has not yet been fully proved. There is now a scheme for enclosing this ore ground and excluding the sea from it entirely. The further the ore goes seaward, the thicker becomes the limestone roof, which, from being the thin end of a wedge landwards, increases as it goes outward until it becomes 103 feet thick. The new wall, if made, will enclose 170 acres: it will be 6750 feet long, and the mode of construction will not be the same as in the former case, for it has been found by experience that a more flexible structure is needed. The concrete wall is liable to be fractured under certain circumstances, and it has been decided that if another wall is to be built, it shall be of a more flexible character. The main bank of the wall will probably be of limestone rubble, faced with blocks of concrete pitched pell-mell in order to break the force of the sea. There will be a small embankment of slag or limestone, and the space between the two will be filled in with clay. In order to make the structure water-tight a heart of clay puddle will be brought up inside to several feet above high-water mark of ordinary spring tides, and it will be also protected by sheet piling driven into the ground sufficiently far to prevent any water percolating through.

---

* *American Journal of Science*, vol. viii. pp. 153–156; with two plates.

† *Ibid.*, vol. viii. pp. 225–226; with plate.

‡ *Iron and Coal Trades Review*, vol. lix. pp. 151–152.

**Mining in the Lake Superior District.**—A paper covering 40 pages, on the methods of mining iron ore in the Lake Superior region, has been prepared by N. P. Hulst.* The paper gives a complete account of modern mining engineering practice in the Lake Superior district.

W. L. Hildburgh † gives some general notes on mining practice in Michigan. Amongst other details reference is made to the Cornish and Worthington pumps and to the water-winding apparatus, the electric locomotives and other means of haulage, the winding engines, air compressors, surface arrangements for handling ore, and other details.

W. Fawcett ‡ considers the present conditions of shipping on the Great Lakes in relation to the iron trade and transport of ore. Particulars of the present vessels and of the proposed conditions are given.

**Diamond Boreholes.**—H. M. Lane § discusses the amount of dependence that can be placed upon the apparent position of the end of diamond boreholes, and quotes instances of inclined boreholes in the Chapin and Hamilton mines in the Lake Superior district, where the boreholes had deviated very greatly both laterally and vertically in the case of inclined holes. Reference is made to MacGeorge's and to Nolten's instruments for surveying boreholes. In the former there is a tube filled with gelatine solution, in which a magnet and plumb-bob floats; the gelatine solidifies when the tube is left in the hole, so that its direction can be determined. In the latter instrument a glass tube is etched with hydrofluoric acid when *in situ.* || The cause of the deviation is investigated, and is ascribed in part to the friction of the rods against

---

* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xv. pp. 62–104.

† *School of Mines Quarterly*, vol. xx. pp. 142–168.

‡ *Iron Age*, May 4, 1899, pp. 8–10.

§ *Mines and Minerals*, vol. xx. pp. 7–9, 49–51.

|| Kendall and others have devised clockwork arrangements, attached to the rodding, for locking a magnetic needle in the borehole, so as to determine its orientation and dip.—H. G. G.

the side of the hole, which tends to divert the tool upwardly and to the right when running in the direction of the hands of a watch in uniformly hard material in an inclined boring. In hard material, the upward drift is greater and in soft material the sideways drift is more pronounced, probably owing to the increased wear on the opposite side of the hole. The inclination of the strata also has some effect. The proper disposition and use of the holes for exploratory work is also discussed.

G. C. M'Farlane * describes a method for determining the dip and direction of a borehole. It depends on the electric resistance offered by a wire dipping into a mercury cup attached to the end of the rods. As the rods are turned, the level of the mercury changes, and the alteration in resistance is measured by a tangent galvanometer. The resistance due to the position assumed by a magnetic needle gives the direction.

Barillon † has used a plumb-line for testing the deviation of vertical boreholes. The plumb-bob is of such a size as just to fit the borehole, and in case the suspending wire touches the sides at the top from the deflection of the bob, the supporting pulley for the line is brought to the centre again for deeper observations. Within limits the method is of considerable use.

**Winding Engines.**—At the Greater Britain Exhibition at Earls Court a working model was shown of a traversing engine, patented by W. Morgans, for winding from very great depths. The model represented to a scale of one-sixth the winding engine for the new vertical shaft (3000 feet) at Dolcoath mine.

It is a double cylinder and two-rope winding engine fixed on a steel framing so as to be self-contained and as independent of masonry foundations as a marine engine, locomotive, or a steam travelling railway crane. It is mounted on wheels for slow traversing on two short railway tracks whilst the engine is winding. The traversing is done automatically by ordinary rack-and-pinion gear which ensures the regular coiling of the rope and prevents overlapping, but if it became disengaged or got out of order it would not disable the engine, which would then resemble a self-contained fixed winding engine working with overlapping ropes.

The engine, of which the exhibit is a model, has two cylinders

---

* *Engineering and Mining Journal*, vol. lxviii. p. 341.

† *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 108–111

24 inches diameter by 60 inches stroke, with equilibrium valves, and a drum only 10 feet diameter by 21 feet long, capable of accommodating two ropes each for winding from a depth of 3000 feet. It is intended to compound the engine, after sinking is completed, by replacing one of the cylinders with a low-presture cylinder.

The application of the ordinary type of direct-acting engines, whether with cylindrical or conical drums for winding from depths of from 3000 feet to 6000 feet, involves the use of drums of excessive diameters and of steam cylinders of excessive sizes. These conditions are unfavourable for the economic use of steam, and the great mass of the moving parts of such engines is unfavourable to economy of time in starting the wind quickly. The very large diameter of the drums of such engines renders it impracticable to employ engines of a proportionately long stroke to secure a proper ratio between the periphery speed of the drums and the piston speed of the engines. The traversing principle enables the most advantageous ratio to be adopted for any depth, and the risk of over-winding is reduced to a minimum. The drum, being cylindrical throughout, admits of the use of a balance rope in vertical shafts.

The development of the mining industry in Northern Michigan has necessitated the adoption of very powerful winding engines, the depths being great and the load to be raised heavy. A fine engine of this character just erected at the Tamarack mine is described.* The engine is of the diagonal type, and has four cylinders, each 36 inches in diameter by 60 inches stroke, connected two and two on to two crank-pins. The main bearings are 24 inches in diameter by 42 inches long, and the drum is 25 feet in diameter and 24 feet 6 inches long, and is provided with spiral grooves for 1½ inch rope. These spirals are, however, only provided at the ends of the drum, since the depth of the shaft being 6000 feet, a drum of an enormous size would have been needed to carry out the principle of the spiral drum in its entirety, and hence the middle portion of the drum is cylindrical. The total weight of the drum and shaft is 300,000 lbs. The load to be raised consists of 6000 feet of 1½ inch rope, weighing 21,800 lbs., the cage weighing 4200 lbs., two cars 4000 lbs., and the rock mined 12,000 lbs., making a total of 42,000 lbs. suspended on one rope. Part of this is, however, balanced by the descending cage. The speed of hoisting is 4000 feet per minute. The engines are fitted with Corliss valves, the reversing gear being peculiar, but not easily explained without drawings.

---

* *American Machinist*, vol. xxii. pp. 833–837; *Engineering*, vol. lxviii. p. 361.

**Electric Transmission of Power.**—C. Pfankuch * describes the electric power and lighting plant at the Hollertszug iron mine at Herdorf on the Sieg.

**Mine Timber.**—Arthur Lakes † has published an article on mine timber, its choice and preservation, in which he reviews the various timbers used, mentioning some curious kinds, the use of which is necessitated in high and arid regions. He also considers methods of preservation.

**Electric Rock Drills.**—F. Hille ‡ deals with electric transmission and the use of electric drills in mines, advocating their introduction into Canada. A large number of illustrations of various forms of drills, both percussive and rotary, are given, together with particulars of their use in various countries.

C. Le Neve Foster, § in his annual report, refers to the use at a quarry near Darmstadt of some excellent percussive drills driven by electricity, and states that there are about one hundred of these drills in use throughout Europe. Of electric rotating drills the fourteen in operation in this country are found only in the Cleveland district. With one of these about seventy or eighty holes per shift can be drilled, and a yield of 140 tons of ironstone easily got.

C. Schraml ‖ mentions the experimental use of rotary electric drills at Hallstatt. One of these is a Siemens-and-Halske machine, and the other two were made by the Union Company. A Bornet drill is also to be tried. The three drills above referred to had been nine months in continuous use at the time the author wrote, and had given general satisfaction.

**Pumping Plant.**—James Davison ¶ describes the pumping plant at the Stank and Yarlside mines, where six, and sometimes seven, engines are at work raising water from levels down to the depth of 720 feet. The average quantity raised is 5662 gallons per minute. The pumps are of the Cornish and the Hawthorn-Davey types, and these give about equal duties. The leading dimensions of the engines and pumps are given, with particulars of their working.

---

* *Dingler's Polytechnisches Journal*, vol. cccxii. pp. 74–77.

† *Mines and Minerals*, vol. xix. p. 427.

‡ *Journal of the Canadian Mining Institute*, vol. ii. pp. 166–185.

§ *Reports of H.M. Inspector of Mines for North Wales*, 1899, p. 23.

‖ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 237.

¶ *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 296–304.

Illustrations have appeared[*] of the new high-pressure Cornish engines at the Basset mines, Cornwall. The steam-cylinders are placed above and at opposite ends of the beam to which the rods are connected, and are 40 and 80 inches in diameter respectively, with strokes of nine and ten feet, while the rods have a stroke of 13 feet.

**Ventilation of Iron Ore Mines.**—A simple method of ventilating the working places has been adopted in the mines of the Upper Hartz.[†] It consists merely in inserting a brass nozzle into the funnel-shaped end of the air-pipe. A jet of water is forced through the nozzle and the water collecting on the sides of the pipe is drained off through a vertical pipe dipping into a water seal. The pressure of water used is 5 to 7 atmospheres, and the method is found to answer satisfactorily with air pipes as much as 200 yards in length.

**Fire-damp in Iron Ore Mines.**—J. L. Hedley and W. Leck[‡] state that until last year no fire-damp had been found in a Cumberland iron ore mine, and then only at the Montreal Mine, Cleator Moor, where coal and iron ore are drawn up the same shaft. Fire-damp had also been traced to some extent in the Hodbarrow Mine, in 1898, a small quantity which had collected in a cavity in the roof having ignited at a miner's candle. In Furness fire-damp has been found at most of the mines. Ten accidents from explosions of fire-damp in iron ore mines have been reported, whereby twelve persons were injured. In the Montreal Mine, the geological formation explained the presence of gas, but in the other mines the decomposition of mining timber, especially in places where water is percolating, is probably the cause of the phenomenon. Fire-damp is a factor to be reckoned with in mining iron ores. Old workings, which had been abandoned for some considerable time and were only partially closed, were, on being reopened, responsible for some of the accidents, and although the gas is not met with in large quantities, there was sufficient to give the persons concerned more or less serious burns. Good ventilation and precautions on the lines taken in collieries are considered requisite. In the discussion that followed the paper, Bennett H. Brough referred to a paper he contributed to the

---

[*] *Engineer*, vol. lxxxvii. p. 471.

[†] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlvii. p. 205.

[‡] *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 284–289.

North of England Institute ten years previously, in which there was a history of the occurrence of gas in metalliferous mines, and cited further cases in which fire-damp had been found in iron ore mines.

## III.—*MECHANICAL PREPARATION.*

**The Washing of Furness Ore.**—W. Kellett* describes the machinery and process of iron ore washing at the Park Mines of the Barrow Hæmatite Steel Company, where 350,000 to 500,000 tons of ore are raised yearly. Most of the ore is not washed, but a certain proportion has to be freed from sand and clay. This ore is separated underground and treated separately in Blake crushers. The material is washed in a trough, in which it is further broken up by knives on a revolving shaft and then passes to a washing drum. This is made of boiler plate, 19 feet long and 4½ feet diameter, furnished on the inside with a double-threaded worm made of 3-inch angle iron, riveted to the drum at a pitch of 20 inches. The spaces between the threads of the screw are furnished with spikes riveted to the drum. The last 4 feet of the discharge end of the drum is perforated with ⅝-inch holes. The drum is carried on two sets of rollers, and is revolved by spur gearing at nine revolutions per minute. The discharge end is 19 inches above the intake end. A stream of water is supplied near the discharge end, and flows out underneath the feeding shoot at the intake end. Large ore from this drum is hand-picked on reciprocating tables, and the small ore is jigged in three compartment jigs. Fine material is buddled. About 110 tons are treated daily, yielding 64½ per cent. of clean ore. Some illustrations of the plant at these mines are appended.

**Magnetic Concentration of Iron Ore.**—H. Wedding † considers the recent progress made in methods for the concentration of iron ores. After briefly referring to non-magnetic methods of concentration, and also to the earlier attempts at magnetic concentration, the author observes that in addition to substances which are magnetic there are a number of others which, under magnetic influence, take up positions at right angles to the lines of force, and he gives a list of some of these diamagnetic substances. They include quartz, calc spar, heavy spar, and the ores of tungsten, uranium, lead, copper, &c. A difficulty was at once experienced in endeavouring to utilise this property in that it was found that the presence of but small quantities of paramagnetic minerals intermingled, or in chemical combination with diamagnetic minerals, sufficed to render the latter magnetic. It was thus found impossible to separate a ferruginous zinc blende from a calcined spathic carbonate. These various difficulties led to more and more perfect electrical separation methods until at last the use of currents of successively greater and greater intensity was adopted for the separation of the various substances. In this connection the author deals with what he considers the best of such separators—that of Wetherill. This he describes and illustrates. Another apparatus also described is that of the Mechernich Company. Apart from improvements in the actual magnetic appliances themselves, others have been elaborated in connection with the treatment of the ore. It is found, for instance, that the degree of fineness to which the ore is ground is a matter of much importance. The author has examined ores under a microscope with polarising attachments and measured the diameter of the grains of various minerals. It is necessary, he finds, to reach a diameter of only 0·01 millimetre if a perfect separation of the different ore grains is to be effected. It would be best in actual treatment to separate the larger portions first in a magnetic separator, and only to grind very fine after this was done. It may happen that in very fine material the particles of even a strongly magnetic body may be so surrounded by a coating of fine non-magnetic dust as to be incapable of treatment in magnetic separators. This is true, for instance, in the case of many Upper Silesian brown hæmatites.

---

* *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 290-295.

† *Verhandlungen des Vereines zur Beförderung des Gewerbfleisses*, 1899, pp. 154–165; with illustrations.

Partial calcination is also occasionally important. Thus a mixture of zinc blende and iron pyrites might not at first sight be considered capable of being separated by magnetic methods, but if a portion of the sulphur of the pyrites is driven off, and magnetic pyrites produced, then the concentration becomes easy. Another point to which the author draws attention is the fact that a mixture of ores which may be very difficult to separate by magnetic methods when in the dry state is capable of easy separation when suspended in water, whether running or at rest, but best when the ore particles are in motion. The author observes, however, that none of the magnetic separators which have been proposed for use in the wet way have given results which would admit of successful application in practice. The author thinks that the right way in such wet appliances would be to make magnetic action play the same part as that played by gravity in ordinary wet methods.

Dealing finally with the question of the subsequent utilisation of the fine iron ore from the concentrators, the author's experiments have shown that the suggestions which have been made for the utilisation of bituminous coal as a binding material, and then coking the mixture, are valueless. The metallic coke so obtained is not strong enough for blast-furnace use. Petroleum residues, tar, pitch, &c., may be made, on the other hand, to give satisfactory results, provided the ore is in a fine enough state of division. Fine ore may be used with advantage in the open-hearth, provided it is charged in cartridge form.

## IV.—*METALLURGICAL PREPARATION.*

**The Calcination of Iron Ore.**—H. Wedding* observes that the calcination of iron ore is usually intended for the purpose of expelling carbon dioxide from the iron carbonate before it is charged into the blast-furnace, and this calcination is effected, as a rule, at the place where the ore is mined, 696 parts of iron carbonate yielding only 458 parts of solid residue. The quantity of material is therefore reduced to 66 per cent. of the weight of the original ore, and transport charges are reduced proportionately. Other iron ores are calcined with a view to reduce the percentage of sulphur, arsenic, or antimony, and occasionally with a view of expelling mercury. Spathic iron ores usually contain small quantities of sulphides, especially copper or iron pyrites, but zinc blende, galena, and other sulphides are also found, and, more rarely, arsenical minerals, especially arsenical iron pyrites and antimony ores, chiefly as fahl ore. These fahl ores often contain mercury. If copper pyrites is present, much care must be taken to eliminate as much as possible of the sulphur; otherwise copper sulphide would form in the blast-furnaces, and this exerts a far greater deleterious effect on iron than does metallic copper.

It is evident that the kiln gases resulting from the calcination of such ores must contain in addition to moisture chiefly carbon monoxide and carbon dioxide, the latter being greatly in excess, especially as an oxidising atmosphere is, as a rule, desired. These gases do not affect plant growth injuriously. If, however, sulphides are present, sulphur dioxide is formed and also sulphuric acid. Sulphur vapour may also form, and this on contact with the atmosphere also forms sulphur dioxide. Gases of this composition, even when very greatly diluted, act most injuriously on plants. Arsenious and antimonial fumes are equally devastating, and mercury fumes are also very poisonous to plant growth. The composition of the gases resulting from the calcination of spathic carbonates is such that they cannot be put to any use, and they are consequently generally allowed to escape into the air. On the other hand, it may become necessary to prevent this for reasons above referred to. The author has visited the calcining plant at Kotterbach, in Upper Hungary, and this he now describes. Here two spathic carbonate lodes are mined, which also contain irregular bunches of argentiferous and mercurial tetrahadrite. The spathic carbonate as mined contains:—

---

* *Verhandlungen des Vereines zur Beförderung des Gewerbfleisses*, 1899, pp. 185–209; with plates.

| $FeO$. | $Fe_2O_3$. | $MnO$. | $CaO$. | $MgO$. | $Cu$. | $Sb$. |
|---|---|---|---|---|---|---|
| 43·24 | 0·60 | 2·01 | 0·30 | 5·07 | 0·41 | 0·06 |

In addition it also contains 0·05 per cent. of mercury, 0·78 of sulphur, 30·39 of carbon dioxide, and 0·47 of baryta.

Near the surface the carbonate is changed into brown hæmatite, and an analysis of this shows it to contain 0·28 per cent. of sulphur, 0·21 of antimony, and 0·14 of mercury.

The spathic ore as it comes from the mine is first submitted to mechanical preparation, and is subsequently calcined in a plant consisting of thirty-six iron shaft-calciners in two rows. The older of these kilns are cylindrical at the top, and conical from this part downwards. The more modern of the kilns are narrower at the top, expanding conically downwards for about three-fourths of their total height, and then narrowing again. The older kilns are of 988 cubic feet capacity, while the more modern ones have a capacity of 1130 cubic feet. The former take a charge of 56 tons, and the latter of 64 tons of raw uncalcined ore. The modern kilns yield 8½ tons in twenty-four hours, with a consumption of 2·16 tons of coke per ton of uncalcined ore. The dimensions of the modern form of the kilns are as follows:—Total height, 13 feet 5 inches; width at throat, 8 feet 6 inches; width at ten feet from the top, 12 feet 1 inch; width at bottom, 8 feet 6 inches. The kilns are provided with hinged covers and central take-offs provided with automatic stop-valves that close them when the covers are open. The gas is drawn off by a Koerting steam-injector in the main pipe, leading from the kilns to the condensing towers, which are coupled in series of two. These latter are of wood, and are each provided with two grids, on which are placed pieces of limestone kept wet by a constant shower of water, one tower serving for a group of twelve kilns. The products of the condensation collect partly in the gas leads, and partly in the settling tanks connected with the condensing towers. Three products are thus obtained, *i.e.*, flue dust from the gas leads, and two kinds of slimes. In analyses given these are shown to have the following compositions:—

| | Flue Dust in front of Injector. | Slime behind Injector. | Slime from the Settling Tanks. |
|---|---|---|---|
| | Per Cent. | Per Cent. | Per Cent. |
| Loss on ignition . . . | 82·19 | 76·93 | 49·63 |
| Total mercury . . . | 78·10 | 58·50 | 33·13 |
| $HgO$ . . . . . . | 9·80 | 5·85 | 6·60 |
| Residue . . . . . | 8·49 | 6·54 | 22·10 |
| $CuO$ . . . . . . | 0·21 | 0·25 | 0·37 |
| $PbO$ . . . . . . | 0·16 | 0·11 | 0·22 |
| $Fe_2O_3$ . . . . . . | 4·03 | 13·13 | 14·83 |
| $Al_2O_3$ . . . . . . | ... | 1·18 | 2·82 |
| $Mn_3O_4$ . . . . . . | 0·62 | 0·79 | 0·50 |
| $CaO$ . . . . . . | 1·78 | 0·63 | 6·70 |
| $MgO$ . . . . . . | 0·37 | 0·70 | 3·58 |
| $AsO_2$ . . . . . . | 0·51 | 1·03 | 0·88 |
| $SbO_2$ . . . . . . | 2·49 | 1·16 | 1·27 |
| Total S . . . . . | 0·88 | 3·66 | 1·45 |
| Cl . . . . . . | 0·33 | 0·87 | 1·54 |
| $H_2O$ . . . . . . | 9·00 | 29·00 | 51·00 |

The kiln gas also contains some sulphur dioxide, about one-half of which is removed in the first condensing tower, and the greater part of the remainder in the second tower. The mercurial residues are treated together with fahl ores, also obtained in the mine workings, in furnaces of the Czermak type as used at Idria, and the gaseous product is conveyed by two cast iron pipes to a system of clay pipes cooled on the outside with water. These pipes are of elliptical section, and end under the surface of water contained in an iron cement-lined tank. In this tank a residue collects which contains considerable quantities of mercury, both in the metallic state and as insoluble mercury compounds. An analysis given shows it to contain 60 per cent. of mercury, and the residue being submitted to pressure, the mercury escapes and is collected. The residues are then again submitted to calcination, and more mercury results.

# REFRACTORY MATERIALS.

**Moravian Fireclay.**—In the *Transactions of the Bohemian Chemical Society*, F. Kovar and A. Haskovec describe the fireclay of Vranova, in Moravia. Two varieties are met with—one a white grey clay with 34 per cent. of water, and the other a dark grey clay. Both are well adapted for industrial purposes.

**Firebrick Manufacture in the Ural.**—The first firebrick factory that has yet been laid down in the Ural is in course of erection near the Lysoa station of the Parm-Tjamen Railway. Ten ovens are being erected. These will have a capacity of three million bricks a year, but it is hoped soon to further enlarge the works.*

**Magnesite.**—Magnesite may be looked upon as the most fire-resisting material that exists.† The temperatures that exist in modern furnaces being so high that not even Dinas bricks will stand them for long, it became necessary to use a more fire-resisting material, such as magnesite. This, it is pointed out, is used either in the form of bricks or stamped down with tar or otherwise. The bricks are made of a mixture of magnesite burnt at a very high temperature, and of another portion which can still take up some water. Some binding material, such as clay, is also used in greater or smaller quantity. The whole is shaped in a hydraulic press and then burnt at the very highest temperature it is possible to attain in a magnesia-lined furnace. The magnesite used for this purpose is chiefly obtained from Styria and Eubœa. It is also found in Lapland, but this magnesite has not yet come into use.

**Graphite.**—E. G. Acheson ‡ reviews the history of graphite and its manufacture, the various methods employed or proposed being briefly mentioned. Statistics for the six years 1890 to 1895 inclusive give the world's production as 73,751, 57,220, 54,280, 55,810, 46,951, and

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 312.

† *Ibid.*, vol. xlvii. p. 149.

‡ *Journal of the Franklin Institute*, vol. cxlvii. pp. 475–486.

53,955 short tons. This is an average yearly production of 56,994 tons.

The author has found that a large quantity of graphite is formed in the electric furnaces used in the manufacture of carborundum, and is probably due to the secondary decomposition of that body after its formation. This takes place especially when coke from impure bituminous coal is used, but not when comparatively pure coke is used. It is intended to manufacture graphite in this way, and one of the varieties consists of graphite mixed with amorphous carbon which is suitable as a foundry facing.

**The Preliminary Examination of Fireclays.**—W. Cronquist* observes that the method of examination of a clay is of a twofold character, being partly chemical and partly mechanical. At the Stockholm Geological Bureau the method in use is as follows:—The clay is air-dried, and is then boiled with hydrochloric acid of 1·12 specific gravity, until the undissolved sand is as white in appearance as can be obtained. It is then filtered off. The residue consists of sand and gelatinous silica, and is boiled in a silver dish with caustic soda. The fused mass is treated with water, and the sand remaining is weighed as such. This latter is then further investigated. The presence of mica usually causes weak bricks. The various analyses made at Stockholm have shown the clays to contain from 47 to 72 per cent. of silica. Analytical results, while helping to show the degree of fire resistance likely to be shown by clays, are yet inconclusive, while the physical properties of the material are not shown by chemical tests. For instance, the most valuable property of all, plasticity, is only to be ascertained by direct tests. A clay is really chiefly a hydrated silicate of aluminia in a colloidal condition. By boiling with water, clay slates can be brought into a plastic condition, and they can also otherwise be made to take up water and become plastic, and it would seem as if continued rubbing of the felspar granules against other and harder minerals in the presence of water is the cause of the formation of clays. The author describes the practical tests to which the clays are submitted. These are of the usual kind. One such consists in making a series of small crucibles, such as are used in the dry iron assay, air-drying these for four to six days, and then at 100° for two days. The crucibles are then fired side by side with others of some well-known clay, and the comparative behaviour noted.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 522.

# FUEL.

## *CONTENTS.*

| | | PAGE | | | PAGE |
|---|---|---|---|---|---|
| I. | Calorific Value . . . . | 339 | VI. | Natural Gas . . . . | 364 |
| II. | Coal . . . . . . | 341 | VII. | Artificial Gas . . . | 365 |
| III. | Charcoal . . . . . | 352 | VIII. | Coal-Mining . . . . | 366 |
| IV. | Coke . . . . . . | 352 | IX. | Coal-Washing . . . | 392 |
| V. | Liquid Fuel . . . . . | 358 | | | |

## I.—*CALORIFIC VALUE.*

**Calorimetry.**—C. L. Norton[*] has devised a modified form of Berthelot bomb. It is made of aluminium bronze in two screwed halves with special valves and joints.

Bryan Donkin[†] has plotted the heating power of fuels, including 71 oils, 619 coals, 12 cokes, 13 peats, and 10 woods as given by various authorities.

The Bavarian Association of Boiler Owners has published in tabular form[‡] the calorific powers of thirty-eight samples of coals, of sixteen samples of brown coals, and of five samples of coke, made on behalf of the Association between the years 1896 and 1898.

**Tests of Coal.**—J. W. Hill[§] has published an elaborate account of some comparative tests of bituminous steam-coals available in the Cincinnati market. The investigation was undertaken with a view to obtaining a set of factors by means of which the prices asked by dealers for different kinds and grades of coal could be reduced to a uniform basis for the comparison of tenders. The experimental work embraced (1) a practical steam test of each kind of coal (of which there were over fifty) under uniform conditions for a period of sixteen hours; (2) a proximate chemical analysis; and (3) a calorimetric determination of the heating power of each kind of coal.

---

[*] *Proceedings of the American Association for the Advancement of Science*, 1898, p. 132.

[†] *Colliery Guardian*, vol. lxxviii. p. 61.

[‡] *Zeitschrift des bayer. Dampfkessel Revision Vereins*, April 1899; *Zeitschrift des Vereines deutscher Ingenieure*, vol. xliii. p. 566.

[§] *American Society of Civil Engineers' Proceedings*, vol. xxv. pp. 142–200.

**Pyrometry.**—In a presidential address C. Barus * deals with long-range temperature and pressure variables in physics, and remarks that there are few phenomena in physics which have not in some way or other been impressed into pyrometric service, often, indeed, by methods of exquisite physical torture. Amongst others, solid expansion, vapour pressure, ebullition, dissociation, heat conduction, colour and the spectrum, polarisation, and wave lengths of sound have all been experimented with and used to some degree. On the other hand, fusion, specific heat, gas expansion, and thermo-electricity have given methods which are much more readily available and useful. The history of these applications is traced briefly but in a most interesting manner, and the subject of high pressure is similarly treated.

A note has appeared † dealing with the various pyrometers made by E. Brown. In one form the expansion of a thin and therefore easily heated platinum strip is compared with that of a larger mass of the metal frame, and in another form the expansion of platinum in a water current passing through a tube in the furnace is measured. Autographic recorders are attached.

Illustrations have appeared of Callendar's ‡ recording pyrometer. Essentially the instrument consists of a Wheatstone bridge, in which the movement of the slider along the bridge wire is automatically effected by relays worked by the current passing through the galvanometer between the bridge arms. According as the galvanometer coil moves in one direction or the other, a relay circuit is made through one of two electro-magnets, each of which releases a brake mechanism on a clock, and the clocks are connected by differential gearing with a recording pen. The slider moves with the pen so as to restore the balance through the coil, which thereupon returns to its zero position and cuts out the relay, thus stopping the clock.

---

* *Proceedings of the American Association for the Advancement of Science*, vol. xlvi. pp. 65–92.

† *Iron Age*, vol. lxiii., April 6, 1899, pp. 10–11.

‡ *Engineering*, vol. lxvii. pp. 675–676.

The Uehling and Steinbart pyrometer [*] is described in detail. It is of the pneumatic type, and depends on the phenomena observable when gases are allowed to escape from small openings. For a given rate of draught the actual quantity of air that will pass through an opening is dependent on the temperature of the air so passing, and the higher its temperature, the less will be its volume when subsequently cooled down to a given temperature. Inversely the rate of flow is dependent on the temperature. Thus in the case of a tube closed at both ends except for a small opening in each, and connected with some means for producing a current of air through it, if the air is pulled in through one opening, then heated to the desired temperature in the tube, and then pulled out by the suction pump and brought to its original temperature, differences in the velocity of the draught will be noticeable at the two openings. By means of manometers such variations in velocity and pressure can be watched and noted, and it is on principles such as these that the pyrometer in question is based. The description is accompanied by numerous illustrations showing both the pyrometer itself and diagrams obtained by its use in practice.

## II.—*COAL.*

**Occluded Gases in Coal.**—Broockmann [†] has published an article on the gases occluded in hard coal, in which he gives a review of the various investigations which have been made, together with analyses, and a discussion of the relation of occluded gases to coal-dust explosions.

**Coal in North Staffordshire.**—A paper read at the Geological Section of the British Association at Dover by Walcot Gibson referred to the coalfields of North Staffordshire. He considers that the Permian rocks there should be considered as part of the Carboniferous series, as they lie conformably with the coal measures. The productive coalfield reaches farther west than might have been expected, thus increasing the productive area.

---

[*] *Stahl und Eisen*, vol. xix. pp. 431–438; 18 illustrations.

[†] *Glückauf*, vol. xxxv. pp. 269–270.

**The South Wales Coalfield.**—W. Galloway [*] has published a course of lectures on mining. The first of these deals with the South Wales coalfield, and has a map appended showing the position of the steam-coal and anthracite collieries.

**Coal in Kent.**—At the Dover meeting of the British Association two papers dealing with the South-Eastern coalfield were read by R. Etheridge and by Professor Boyd Dawkins. The prospective value of the field, the relation with the Franco-Belgian and the Western coalfields, and the present conditions of exploratory work, were amongst the features treated. The boring at Ropersole is now about 1774 feet in depth, and has penetrated 197 feet into the coal measures, showing two seams in that thickness. It has established the fact that the Dover coal measures extended northwards for a distance of eight miles and beyond in the direction of Canterbury. The coal measures set in in Kent at a sufficient distance to the north-east of Brabourne to allow of the presence of the Carboniferous limestone and millstone grit. These probably dip at the same high angle as the Devonian below. Their south-western boundary could only be accurately defined by further borings, such as those which were now being carried on at Ottinge, about two and a half miles to the north-east of the scarp of the Downs, and six miles to the south-west of Ropersole. Their range to the north and the east still remained to be proved.[†]

In a recently published note [‡] on the Kentish coalfields, the geological data are reviewed with the aid of sketch maps and sections, and an account is given of the state of the sinkings near Dover.

**Coal in Ireland.**—Some particulars of the Castlecomer mines in North Kilkenny and Queen's County have recently appeared. Workable coal is believed to exist over about fifty square miles, and several collieries are at work, but the nearest railway is nine miles distant. Over four hundred men are employed in and about the mines, which depend entirely on the land sales. The mines are free from fire-damp.[§]

[*] *Proceedings of the South Wales Institute of Engineers*, vol. xxi. (Appendix).

[†] *The Times*, September 15, 1899.

[‡] *Engineer*, vol. lxxxvii. pp. 508–509.

[§] *Irish Daily Independent*, through the *Iron and Coal Trades Review*, vol. lviii. pp. 1091–1092.

**Coal in Austrian Silesia.**—J. Poppe* describes the newest portion of the workings of the Ostrau collieries in Austrian Silesia. The shafts in the northern portion of the workings attain a maximum depth of 1959 feet. Over a dozen seams are opened up by these shafts. Some of these yield caking coals, three mentioned yielding from 18 to 34 per cent. of volatile constituents, and containing from 2·6 to 4·2 per cent. of ash. With regard to the thickness of the seams, they appear to be usually less than a yard, though thicker ones also occur. Shaft No. II., raising coal from two seams whose average thickness is about 28 inches, winds coal to the amount of 1·13 ton per miner employed. Much fire-damp has been met with occasionally, and this was particularly the case in connection with a cross-cut which struck a thick seam at a distance of some 5300 feet from the shaft. This seam reached a thickness of as much as 8 feet, and much difficulty was at first experienced on account of the gas. Subsequently, however, the seam proved less gassy. The author explains how the various difficulties were overcome, and the seam opened up, despite trouble from water. It was found necessary to sink a ventilating shaft.

A comparison is given of the results obtained by the use of the Brandt hydraulic drill as compared with hand-work. The average distance driven per month by hand was 50 feet 9 inches, while by the use of the power drill a distance of nearly 230 feet was driven in the same time. They were not, however, satisfactory in soft rock, having to be replaced by hand-labour or Elliot machines, the Brandt machines being too powerful in their action. The Eleanora group of seams opened up recently at these collieries comprise a group of seams of caking coal, one yielding 33·5 per cent. of volatile constituents, and containing 3·7 per cent. of ash, and another 30·2 per cent. of volatile constituents and 2·45 per cent. of ash. The opening up of these seams has entailed the necessity of greatly increasing the number of the coke-ovens possessed by the colliery. These numbered 76, and a large central coke-oven plant is now proposed.

◆

**Coal in Lower Austria.**—According to V. Hanisch † the hills which rise about 8·7 miles to the west of Wiener-Neustadt consist of Triassic limestones, and on this rests the Gosan coal-bearing beds. A basin has been produced by the formation of these hills, and the coal-seams on the northern portion of this basin are those which have been chiefly investigated. The workings extend for a distance of 8½ miles from Lanzing along the foot of the hills. Those which are now in activity are three in number, the deepest shaft being 689 feet in depth. There are more than 16 old workings now abandoned. The seams vary considerably, being much faulted. The coal is described as a short-flamed "sand" coal, partial assay results showing from 6·81 to 9·72 per cent. of ash and 0·67 to 1·35 per cent. of sulphur, and calorific powers of 5767 and 5953 calories. There is absolutely no fire-damp noticeable in the mines. The coal as mined is mostly small, and no attempt is made at any separation into sizes. It finds a ready sale for boiler purposes. The author gives further details as to the workings and their equipment.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 217–220, and 235–237; with sheet of illustrations.

† *Ibid.*, vol. xlvii.; *Beilage*, pp. 48–49.

**Coal in Hungary.**—F. Schaffer [*] gives the results of recent borings for coal at Mariathal and Bisternitz, in Pressburg County, Hungary. Coal was met with at a depth of 50 yards. It is of good quality, with a calorific power of 5000 calories and 12 per cent. of ash.

K. Redlick [†] describes the remains of two kinds of mastodons found in the seam of coal at Neufeld, Hungary. This seam is about 12 yards in thickness, and is, he considers, probably of Pliocene age.

**Coal in Servia.**—E. Hegner [‡] has published an exhaustive account of the coal-mining industry of Servia. Although Servia has more than enough coal and lignite for its needs, foreign coal is imported every year in increasing amounts. Not more than a dozen collieries are in operation, and most of these are worked in a very primitive manner. The Morava Tertiary basin, near Alexinatz, is described in detail. It is twelve miles long and five miles wide.

**Rare Elements in Liége Coal.**—A. Jorissen [§] has found in the dust from Liége coal, besides a considerable quantity of iron, some copper, lead, arsenic, and zinc, and traces of selenium, antimony, molybdenum, bismuth, nickel, and cobalt.

---

[*] *Verhandlungen der k.k. geologischen Reichsanstalt*, 1899, pp. 169–174.

[†] *Ibid.*, 1899, p. 147; *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 352.

[‡] *Montan-Zeitung*, vol. vi. pp. 211–213.

[§] *Annales de la Société Geologique*, vol. xxiii. p. 101.

**Coal in France.**—M. Martinet* has published an article on the early working in the Commentry coalfield, in which he describes the deposits and various phases of working.

**Coal in Upper Silesia.**—C. Gaebler† describes the great Orlau fault in the Upper Silesian coal measures. His paper throws much light on the geological structure of this important coalfield. The fault has a maximum height of 4000 yards, the average height being 1600 yards.

**Brown Coal in the Rhineland.**—Dr. Niessen‡ has issued a report on the brown coal mining in the Rhineland, in which he describes the deposits and working of the mines.

**Coal in the Donetz Basin.**—Captain Khudintzov§ gives a short historical and statistical account of the development of the coal industry of the Donetz basin, which has now begun to supply coal for the Baltic fleet. The ordinary coals are divided into five groups, according to quality and composition; the lowest quality having a specific gravity of 1·25 and 75 to 80 per cent. of carbon, and the highest a specific gravity of 1·35 to 1·4 and 90 to 93 per cent. of carbon. Anthracite with a specific gravity of 1·4 to 1·8 and 93 to 95 per cent. of carbon also occurs. The question of analyses of coal and the necessity for systematic analyses are discussed at length, in relation more especially to the classification of the coal at the colliery. A large number of assays and analyses of the coals are appended and discussed.

**Coal in Canada.**—The summary report of the Geological Survey of Canada for 1898 points out that the great value of the remarkable coalfield at Crow's Nest Pass is now in a fair way to be realised, and from now onward continuous shipments of excellent coke will doubtless be made from it to the metallurgical works of Kootenay. The principal coal-seam opened yields 5½ feet of workable coal.

It is also noted that the overthrust faults in the Cretaceous coal-bearing district of Crow's Nest Pass, on the eastern side of the Rocky Mountains, leads to the expectation of finding coalbeds of Cretaceous age below Palæozoic limestone. This peculiarity in the structure is adduced as an explanation of the petroleum occurring in rocks of which the surface is of probable Lower Cambrian age, between Crow's Nest and South Kootenay passes in the Rocky Mountains.

---

* *Colliery Guardian*, vol. lxxvii. p. 353.

† *Glückauf*, vol. xxxv. pp. 461–473; with map and section.

‡ *Colliery Guardian*, vol. lxxvii. p. 443.

§ *Morskoi Sbornik*, November 1898, non-official part, p. 137.

In a presidential address * to the Engineering Society of the School of Practical Science of Toronto, W. E. H. Carter described the northern lands of the province of Ontario. His search for mineral fuel merely substantiated previous accounts. The first exposure of lignite on the Abitibi occurs about thirty miles up from the mouth. Some years ago Bell found similar exposures along the Moose River, fifty to eighty miles from those on the Abitibi. It seems probable that in the intervening area other deposits lie hidden at not very great depths.

Harrison F. Bulman † publishes an article on the Sydney coalfield, Cape Breton, in which he gives an account of the collieries of the Dominion Coal Company and of the General Mining Association.

He also publishes an article on the Pictou coalfield, Nova Scotia,‡ in which he gives an account of the collieries, the methods of working, equipment, management, &c.

**Coal in British Columbia.**—According to the annual report of the Minister of Mines of British Columbia, an average sample of the coal mined on the Elk River gave the following analytical results :—

| | |
|---|---|
| Water | 1·80 |
| Volatile matter | 18·70 |
| Fixed carbon | 72·08 |
| Ash | 6·70 |
| Sulphur | 0·72 |

There are twelve seams with a total thickness of 147 feet in 900 feet vertical coal measures.

A number of seams are found in the district, and are being opened up owing to the opening of railway communication.§

**Coal in New South Wales.**—J. H. Ronaldson || reviews the subject of coal-mining in New South Wales, giving a brief account of the geology of the Newcastle or northern district, and of the southern and western fields. Pillar-and-stall working is almost exclusively adopted, and only one mine is subject to gas.

---

* *Engineering Society of the School of Practical Science of Toronto*, No. 12, 1898-99, p. 9.

† *Colliery Guardian*, vol. lxxvii. p. 989-990.

‡ *Ibid.*, vol. lxxvii. p. 1090.

§ *Iron and Coal Trades Review*, vol. lviii. pp. 953-954.

|| *Report of the Seventh Meeting of the Australasian Association for the Advancement of Science*, 1898, pp. 1012-1014.

**Coal in New Zealand.**—According to H. F. Bulman,[*] northward of Auckland there are six or seven small day-drift coal-mines, producing together 70,000 to 80,000 tons of coal yearly. Four of these mines are situated near Hikurangi, and they include the largest, that owned by the Hikurangi Coal Company. Their output in 1897 was 30,663 tons. An average assay of the coals shows:—

| Fixed Carbon. | Volatile Matter. | Water. | Ash. |
|---|---|---|---|
| 54·03 | 39·94 | 3·82 | 2·21 |

A few miles to the eastward, coal is found at Kirepaka, and assays—

| Fixed Carbon. | Volatile Matter. | Sulphur. | Water. | Ash. |
|---|---|---|---|---|
| 46·44 | 47·80 | 0·54 | 4·66 | 1·10 |

A few particulars of these various workings are given.

The best equipped colliery and the largest coal producer in the North Island is the Taupiri Extended. It is situated near Huntley, a station on the main line of railway, sixty-five miles south of Auckland, and close to the river Waikato. The seam worked ranges from 21 to 50 feet in thickness, and gives a brown coal containing about 50 per cent. of fixed carbon. Fuller details are given of this and a neighbouring colliery.

Alexander Mackay[†] has published an article on the coal outcrops of the Tangarakau River, in which he gives a report on the district between Stratford and the river named.

**Coal in South Africa.**—E. J. Dunn[‡] discusses the evidence of the existence of extensive deposits of coal in Cape Colony. Coal-seams which are being worked in the Vereeniging mine, on the north side of the Vaal River, are underlaid by the Dwyka conglomerate, which crops out in Cape Colony with indications of the existence of coal measures. The Dwyka conglomerate is directly overlaid by black carbonaceous shales all round an enormous area. At Kimberley these shales attain a thickness of 240 feet, and some other beds carry 9 per cent. of carbon. At Vereeniging the coal seams lie either immediately upon the conglomerate, or there is a black shale intervening for a few feet with black shale above the coal. It follows that the Dwyka conglomerate is a good bench mark. Below its main body it is useless to search for coal, but above it, either directly, or in some cases perhaps at a considerable height above it, the coal measures and coal were laid down. The total length of the area occupied by the Dwyka conglomerate and its accompanying coal measures is 800 miles from Middleburg, Transvaal, to near Karoo Poort, Cape Colony, and its extreme width 350 miles between Kimberley and East London. Outside this area outliers occur at many places, the Zyferfontein and Boksburg coalfields in the Transvaal belonging to this same horizon. The length of the outcrop of the Dwyka conglomerate, and occupying black shales, coal, &c., exceeds 2000 miles. In 1886 black shale and thin seams of coal alone were known, but now with the light thrown on the subject by the Vereeniging and other extensive coal-mines along the northern edge of the area, the argument formerly advanced that the poverty of the outcrop argued against the existence of coal in workable seams farther in the basin falls to the ground, for the coal seams now being worked within the northern run of the area range from 6 feet of workable coal to over 60 feet. In 1886 the probability of coal being found under the Karoo was predicted on geological grounds alone. The realisation far exceeds the most sanguine expectations. Much discussion on this subject has ensued.

---

[*] *Colliery Guardian*, vol. lxxviii. pp. 297 and 347.

[†] *New Zealand Mines Record*, May 16, 1899.

[‡] Paper read before the South African Philosophical Society, through the *Colliery Guardian*, vol. lxxvii. p. 1185.

Daniel Bellet * gives a detailed account of the coal resources of the Transvaal.

A report † has been issued of a Commission which has been appointed to investigate the coal industry of Natal.

**Coal in Colorado.**—A. Lakes ‡ gives a resumé of R. C. Hills' account of the coalfields of Colorado, with some further particulars gathered by himself. The coal is of Cretaceous age of the Laramie group, and ranges from lignite through bituminous coal to anthracite in the neighbourhood of intrusive rock. There are six independent fields, known as the Raton, South Platte, North Park, Grand River, Yampa, La Plata, besides three small fields of little importance. A sketch map and several sections are given to show the coal-bearing areas and formations, and a short account of each field is given with a few analyses of the coal.

**Coal in Michigan.**—C. Holmes § gives a brief description of the coalfields of Michigan, with a map of the basin showing the various mines. A short account of several of the mines is also given, including sections of the strata passed through, and of the surface and underground arrangements.

---

* *Moniteur des Intérêts Materiels*, vol. xlix. pp. 1905-1906.

† *United States Consular Reports*, No. 379, March 21, 1899.

‡ *Mines and Minerals*, vol. xix. pp. 541–543.

§ Paper read before the Michigan Engineering Society ; *Mines and Minerals*, vol. xx. pp. 59–62.

**Coal in Pennsylvania.**—At a recent meeting of the Engineers' Society of Western Pennsylvania,* A. P. Kirtland described the coal industry of Pittsburgh, the industry on which the prosperity of the city so largely depends. The coal is of superior quality; there is an unlimited quantity of it within easy reach, and exceptional facilities are offered by the geological structure for mining operations. The seam varies from 6 to 12 feet in thickness, and lies mainly above drainage level, the zigzag outcrop extending for 2000 miles. It is this coal that is so largely used in the gasworks of the United States, and makes the well-known Connellsville coke. Recent analyses of the coal gave the following result:—

| | I. | II. |
|---|---|---|
| Volatile matter | 35·470 | 33·80 |
| Fixed carbon | 57·628 | 61·111 |
| Ash | 5·060 | 3·275 |
| Sulphur | 0·915 | 0·828 |
| Phosphorus | 0·012 | ... |
| Moisture | 0·915 | 1·400 |

Beverley S. Randolph † has published an article on the coal region of Georges Creek, Cumberland, in which he describes the geological peculiarities, the qualities of the coal, and the method of working.

**Coal in Utah.**—Don Maguire ‡ describes the coal-mines of Utah. The coal region of that State covers an area of 40,000 square miles, and contains numerous beds of bituminous coal, varying from 3 to 12 feet in thickness. The following are typical assays of the coals:—

| | I. | II. | III. | IV. |
|---|---|---|---|---|
| Moisture | 8·38 | 4·36 | 1·50 | 3·78 |
| Fixed carbon | 40·45 | 45·10 | 50·22 | 44·65 |
| Volatile matter | 46·89 | 46·03 | 44·62 | 50·11 |
| Ash | 3·33 | 4·51 | 3·20 | 1·46 |
| Sulphur | 0·95 | ... | 0·46 | ... |

---

* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xv. pp. 203–221.

† *Mines and Minerals*, vol. xix. pp. 422–423.

‡ *Ibid.*, vol. xix. pp. 438–439.

I. Summit County; II. Winter Quarters; III. Castle Gate; IV. San Pete County. The present production of coal in Utah amounts to about 150,000 tons annually.

**Coal in Virginia.**—I. C. White, State geologist of West Virginia, has issued a geological map of the State on a scale of ten miles to the inch. It well shows the large area of coal-lands yet untouched. Both coal and petroleum are widely distributed throughout the State.

Another new map deserving notice is that of Smyth County, Virginia, compiled by C. R. Boyd. It is on a scale of one mile to an inch, and shows the economic geology of the State, the names of all the mine-owners being distinctly stated.

Andrew Roy * publishes an article on the Thacker coalfield of West Virginia, in which he gives a description of the formations and the extent and manner of their development.

**Coal in Porto Rico.**—M. V. Domenech † states that the mineral resources of the island of Porto Rico have not yet been fully explored. Peat and lignite occur in abundance at various places. On the north coast lignite is found below the Tertiary limestones, but as it contains a large quantity of iron pyrites it has not been developed. In Utuado and near Cabo-Rojo lignites occur which appear to be free from iron pyrites. The peat, which is met with in large quantities, might advantageously be used as fuel in the sugar-works.

**Coal in Algeria.**—Coal has been discovered by C. von Schwarz ‡ at Meuerville near Algiers. There are several outcrops in a ravine, and the coal is, of course, impure, having lost its volatile constituents. In order to ascertain the value of the coal, further investigations are required. The existence of coal in Algeria is now proved, although the possibility of its presence has hitherto been doubted. The coal is found at a place about ten miles from the sea, and about twenty-seven miles from iron ore deposits. The nearest railway station is about sixteen miles distant.

**Coal in Asia Minor.**—The mineral wealth of Asia Minor is very great, but very little has been done to develop it. Iron ore, chrome, iron ore, and coal are abundant. The whole country is covered with abandoned mines that would well repay working under more favourable conditions. Iron is still worked near Samsun, in what was once the country of the Chalybes, so renowned as ironworkers in olden times. The largest known coal area is that of Eregli in the north, about thirty by nine miles. During the Crimean war these mines were worked to supply coal to the allied fleets, but little has been done to develop them since. Smaller areas exist near Ineboli and at Amasra, in the same district. Coal has also been found near Mardin.*

---

* *Mines and Minerals*, vol. xix. p. 472.

† *Ibid.*, vol. xix. pp. 529-532.

‡ Communicated by the Ritter von Schwarz, October 23, 1899.

**Coal in Sumatra.**—The Ombiliën coalfields in Sumatra are a few miles inland from Padang, and are owned and worked by the Dutch Government. They are estimated to contain 197,000,000 tons. The following is an analysis of Ombiliën coal by E. Riley: †—

| | Per Cent. |
|---|---|
| Carbon | 77·62 |
| Hydrogen | 6·08 |
| Nitrogen | 1·11 |
| Oxygen | 12·80 |
| Sulphur | 0·63 |
| Ash | 1·76 |
| Total | 100·00 |

**The Micro-organisms of Coal.**—B. Renault ‡ has examined various varieties of French coals of different geological age. Their origin was evidently wood. He found in these coals various micro-organisms, but is as yet uncertain whether the changes which have taken place in the conversion of wood into coal, are or are not a result of their action. Boghead coals are almost exclusively the result of changes in microscopic algæ. They differ from each other by having originated from different kinds of algæ, several different kinds of algæ rarely being present in any one variety of this mineral. They originated in small lakes. The composition of cannel coal is altogether different from that of Boghead coal, and the author distinguishes three different kinds.

---

* *Edinburgh Review*, vol. clxxxix. p. 534.

† *Iron and Coal Trades Review*, vol. lviii. p. 1136.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 209–210.

## III.—*CHARCOAL.*

**Charcoal Used in Iron-Smelting.**—In some notes on Swedish iron metallurgy, J. Douglas * deals with the amount of charcoal used for iron and steel making in different parts of the world, and quotes from many authorities as to the weight of fuel per ton, the yield of charcoal from wood, and the yield per acre. The statements published vary very widely, but even with the high yield of 29·2 cwts. per acre quoted by Sir Lowthian Bell from Chevandier, large furnaces could not be worked.

Similar quotations and conclusions are given by Major R. H. Mahon † to show the impracticability of charcoal furnaces in India, in his report on the manufacture of steel in that country.

**Gas from Wood.**—By the Riché ‡ system the wood is distilled in vertical iron retorts. The wood is charged in at the top, and charcoal is removed at the bottom. The gases are also withdrawn at the bottom, and are forced to pass over the red-hot charcoal. This reduces the water vapour and carbon dioxide, yielding hydrogen and carbon monoxide. The calorific value of the gas is stated to be 2500 calories per cubic metre.

**Peat Charcoal.**—At a meeting of the Belgian Association of Chemists, Petermann discussed the utilisation of the Belgian peat deposits. He gave analyses of peat from the Campine and from the Ardennes, and showed that it might well be used instead of wood for dry distillation, the products being charcoal, methyl alcohol, acetic acid, and tar.

## IV.—*COKE.*

**By-Product Ovens.**—E. Coppée § discusses the use of by-product coke-ovens, and gives an estimate for the cost price of coke for an output of 840 tons per week with coal containing 25 per cent. volatile matter, and costing 7s. per ton delivered at the ovens, in beehive and in Coppée ovens with and without recovery of by-products. He shows that coke from the latter costs not much more than half the cost of beehive coke. Some discussion ensued upon the varieties of coal suitable for use, and on the nature of the coke produced.

---

* *Journal of the Canadian Mining Institute*, vol. ii. pp. 38–53.

† *Report on the Manufacture of Iron and Steel in India.* Simla, 1899.

‡ *Journal für Gasbeleuchtung und Wasserversorgung*, April 8, 1899; *Zeitschrift des Vereines deutscher Ingenieure*, vol. xliii. p. 464.

§ *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxxviii. p. 439.

Illustrations have appeared of the new Semet-Solvay * coke-ovens at Brackley Collieries, including a general view, a section of the oven, and a plan of the works. The patent car by which the coke is led from the ovens to the conveyor is also illustrated.

J. D. Pennock † discusses the retort oven and the chemistry of its by-products. A description of the Semet-Solvay oven is given, and of the means for determining the temperature in the flues. A number of physical tests are appended to compare retort oven coke with beehive coke. The increased yield in the retort oven is referred to, and explained by the breaking-up of hydro-carbons and deposition of the carbon, as well as by the fact that none of the coke is burnt in the oven. The by-products, including ammonia, benzine, and tar, are considered at some length.

The total volume of gas from a coal containing 33 to 34 per cent. of volatile matter is about 10,400 cubic feet per ton, and from a coal with 20 per cent. volatile matter about 7000 cubic feet per ton. The quantity of gas returned to the oven for heating is from 50 to 55 per cent. if the coal has 32 to 34 per cent. of volatile matter. Less gas is required to coke coals of low volatile composition. Thus Pocahontas coal containing 19 per cent. of volatile matter requires only two-thirds as much gas for coking as Connellsville coal, which contains 32 per cent. The records of gas analysis made hourly in one test are given in full, and show that the methane at the beginning is very high, being 46 per cent., and that it soon falls to 40 per cent., and remains at this figure for about twelve hours, and then begins to diminish until, at the discharge, the gas contains only 10·2 per cent. The hydrogen, on the other hand, starts at 28·9, and is ever increasing, until at the end it has reached 77·0 per cent. The illuminants (olefines) are highest, 6·8 per cent. in the beginning, and gradually diminish until, after sixteen hours, they are practically nil. The carbon monoxide, 9 per cent. in the first test, gradually decreases until in the last test 4 per cent. is found. As an illuminating gas it is not of much value after ten hours. In calorific value, however, it has diminished only slightly.

D. Anderson ‡ discusses the yield of coal in coking, and maintains that it is practically the same in the beehive and in the retort ovens.

G. Schultz,§ in order to obtain a higher yield of benzol and similar

---

* *Iron and Coal Trades Review*, vol. lix. p. 243.

† *Journal of the American Chemical Society*, vol. xxi., July 1899.

‡ *Iron Age*, vol. lxiv., September 28, 1899, pp. 4–5.

§ *Chemiker Zeitung*, vol. xxiii. p. 273.

valuable hydrocarbons, first frees the tar obtained in the coking process from its aromatic hydrocarbons, amounting to about 10 per cent. of the whole, and from the pitch, which amounts to some 60 per cent., and then returns the remaining oily residue to the coke-oven. Here this undergoes further decomposition, more benzol and similar hydrocarbons resulting.

In a presidential address G. Beilby* deals with the smoke and fuel question. The statistics of coal consumption give a general idea of the magnitude of the problem to be dealt with, and form a sound starting-point from which to consider the various remedies which have been suggested. These remedies were broadly divided into two classes:—

1. Improved appliances for the combustion of raw coal, and distribution of the air supply in furnaces.

2. The transformation of the raw coal into smokeless fuel by preliminary treatment, either by destructive distillation in gas retorts or in coke-ovens, or by its conversion into fuel gas by partial combustion in air and steam.

The distillation of coal in retorts, blast-furnaces, and coke-ovens was described generally. The amount of each of the crude products obtained from each source was given as follows:—Gasworks distil 13 million tons, and produce 130,000 million cubic feet of illuminating gas at 650 British thermal units per cubic foot; 650,000 tons of tar; 129,500 tons of sulphate of ammonia; 7 to 8 million tons of soft coke. Blast-furnaces distil 2 million tons of coal, and produce 360,000 million cubic feet of fuel gas at 130 British thermal units per cubic foot; 150,000 tons of tar; 18,000 tons of sulphate of ammonia. Recovery coke-ovens distil 1¼ million tons, and produce 12,500 million cubic feet of illuminating or fuel gas at 600 British thermal units per cubic foot; 62,000 tons of tar; 900,000 tons of hard coke; 11,000 tons of sulphate of ammonia. If beehive ovens were entirely replaced by recovery ovens there would be a further production of 125,000 million cubic feet of illuminating or fuel gas, 620,000 tons of tar, 9 million tons of hard coke, 110,000 tons of sulphate of ammonia.

E. W. Parker † traces the development of by-product coke-making in the United States. The first radical departure from the behive oven was inaugurated in 1891 by the construction of twelve Semet-Solvay ovens. The first plant of Otto-Hoffmann ovens was built at Johnstown, Pennsylvania, in 1895. On January 1, 1898, there were in the United States 280 by-product ovens in operation and 680 in course of construction.

---

* *Journal of the Society of Chemical Industry*, vol. xviii. p. 643.

† *United States Geological Survey, Nineteenth Annual Report.* Part vi., *Mineral Resources of the United States*, pp. 579–585.

Coke-making in the United States may be said to be at the beginning of a new era. It has become the habit of late to designate the prevalent method of coke-making as the wasteful beehive oven, and to criticise unfavourably the action of producers, not only for failing to save the valuable contents of the coal, but also for polluting the atmosphere by the smoke and gases given off. In many cases the latter is the stronger objection. The remoteness of the coking districts from markets for consumption will cause the development of by-product coke-making to be a matter of gradual growth. Profitable markets will have to be found for the by-products; and it must also be considered that increased supplies of fuel-gas, tar, and ammonia, the principal by-products, will necessarily depress prices

**Coke-Oven Plant near Dombrau.**—The coke-oven plant belonging to Messrs. Gutmann, near Dombrau, Austria, is stated by Jičinsky * to have in operation sixty Otto-Hoffmann coke-ovens, arranged in two batteries of thirty ovens each. These ovens were modified in construction by J. Plzák to suit the local conditions of Moravian-Ostrau. Another sixty ovens are in course of construction, and are to be put into operation before the end of 1899. Each of the ovens is 32 feet 10 inches long, 38·6 inches in height, and 39·4 inches broad, and taking a charge of 7·5 metric tons of washed and dry coal, yields in forty-eight hours five tons of lump coke. These ovens, it will be seen, differ in dimensions from the more usual form, and were the result of practical experience, as in the narrower and more rapid ovens the coal available was found not to yield a satisfactory kind of coke. In Karwin, too, at the Johann-Karl pit, 120 of these ovens are at work, and here too they yield a coke which gives general satisfaction. The coke-ovens are arranged for the collection of the by-products. The coal yields 3½ per cent. of tar, 1·2 per cent. of ammonium sulphate, and also benzol. The coke ejector, exhausts, fans, and pumps are driven by electricity.

The by-products obtainable on the dry distillation of coal are considered by Schliemann.† The distillation of tar is dealt with, and it is pointed out that even at 200° C. the tar does not lose the whole of the water it contains. From the water distilled off from the tar various hydrocarbons are obtained. These the author further considers.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii ; *Beilage*, p. 56.

† *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. p. 555.

**The Use of Coke-Oven Gas for Illuminating Purposes.**—F. Schniewind* gives a long account of the Otto-Hoffmann coke-ovens which have been erected at Everett for supplying Boston with illuminating gas. The plant appears to be working satisfactorily, but it is as yet too early to obtain definite results. At present 400 ovens have been erected on tidal marsh-land with good wharfage accommodation, and there is room for 800 more ovens. Coal is unloaded by cranes and grabs from the ship into a 6000-ton bin, whence it is taken by trucks to the storage-ground. The ovens are arranged in eight groups of 50 each. The retorts are 30 feet long, nearly 6 feet high, and 18 inches in average width. The charge is 6 tons, and is introduced by an electrically driven machine. Two sets of gas mains are to be provided to draw off rich and poor gas respectively, but at present all the gas is taken through one main. Poor gas freed from its by-products is used for heating the ovens, and is preheated in regenerators to 1800° F. Producer-gas may ultimately be used for heating the ovens, at least in part, so as to give more elasticity to the system. The time of coking varies from 24 to 30 hours, and the coke is removed from the oven by an electrically driven pusher. Two travelling trucks or pans receive the hot coke, being moved forward gradually, so as to distribute the coke in an even layer to facilitate cooling. Then the pans are tilted to discharge the coke into railway trucks holding 22 to 25 tons. Some of the coke is crushed for household purposes. In 24 hours, 20,000,000 cubic feet, of which half is rich and the other poor gas, is treated in coolers and scrubbers to remove tar and ammonia. The poor gas is used for heating, while the rich gas is freed from sulphuretted hydrogen by iron oxide in the form of bog ore and distributed for illuminating purposes. No attempt is made to remove carbonic anhydride, but the gas is enriched if requisite.

The coal used is washed slack, under one inch in diameter, from Cape Breton. It gives 34·6 per cent. of volatile matter, 59·56 of fixed carbon, and 5·84 of ash on assay. In practice, the yield is 66·99 per cent. of large coke, 1·64 of small coke, and 2·8 of breeze. The gas treatment plant and by-product plant is described, and the nature of the products and advantages of these ovens are discussed.

---

* *Progressive Age*, vol. xvii. pp. 366–370, 386–392.

**The Coking of Indian Coal.**—An appendix to a report by Major R. H. Mahon * on iron and steel manufacture in India contains an account of some experiments made by the author on the coking of Indian coal. A hundred tons of lump coal from various collieries was brought to England and tested by washing and coking in different works. The coals were drawn from the Giridhi coalfield, the Ràniganj and Barákhar area of the Sanctoria coalfield, and two samples from the Jherria coalfield. The washers used were of the Robinson, Luhrig, Coppée, and Murton types. Assays of the coal and coke from the washed coal were as follows:—

| | Giridhi. | | Sanctoria. | | Kenwadih. | | Kustore. | |
|---|---|---|---|---|---|---|---|---|
| | Coal. | Coke. | Coal. | Coke. | Coal. | Coke. | Coal. | Coke. |
| Ash . . . . . . . | 13·0 | 12·00 | 12·00 | 17·25 | 12·5 | 16·10 | 15·10 | 16·70 |
| Volatile matter . . | 26·0 | ... | 38·00 | ... | 23·5 | ... | 24·05 | ... |
| Sulphur . . . . . | 0·4 | 0·63 | 0·43 | 0·48 | 0·5 | 0·85 | 0·75 | 0·82 |
| Fixed carbon . . . | 60·6 | 86·97 | 49·57 | 81·57 | 63·5 | 82·65 | 60·10 | 82·15 |
| Moisture . . . . . | ... | 0·40 | ... | 0·70 | ... | 0·40 | ... | 0·33 |

The Giridhi coke was hard and dense and of good quality, and the Kenwadih coke was also good. Better results might be obtained in practice when the problems of proper washing treatment are more carefully studied.

**Use of Coke for Boiler Firing.**—E. Froitzheim † describes the utilisation of coke breeze for firing boilers. Special fire-bars and forced draught are necessary.

**Earliest Production of Coke.**—John Evelyn, ‡ in his famous diary, writes under date 1664:—"Came home by Greenwich ferry, where I saw Sir John Winter's new project of charring sea-coal, to burn out the sulphur and render it sweet. He did it by burning the coals in such earthen pots as glassmen melt their metal in, so firing them without consuming them, using a bar of iron in each crucible, which bar has a hook at one end, so that the coals being melted in a furnace with other crude sea-coals under them, may be drawn out of the pot sticking to the iron, whence they are beaten off in great half-exhausted cinders, which being rekindled, make a clean, pleasant chamber fire, deprived of their sulphur and arsenic malignity." It was not until the year 1818 that the London Gas Light Company sold the coal thus charred and freed from tar, and gave it the name of coke.

---

* "Report on the Manufacture of Iron and Steel in India:" Government Central Printing Office, Simla, 1899. A copy of this report is in the Library of the Institute.

† *Journal für Gasbeleuchtung*, through *The Iron and Coal Trades Review*, vol. lviii. p. 944.

‡ *Colliery Guardian*, vol. lxxviii. p. 451.

## V.—*LIQUID FUEL.*

**The Origin of Petroleum.**—W. C. Day [*] gives the result of some laboratory experiments on the production of asphalts from animal and vegetable materials. In one series the distillation products from a mixture of fresh herrings and sawdust was passed through a red hot iron pipe and condensed. An oil was amongst the products, and gave, after fractional distillation, a residue resembling gilsonite. From fish alone, a substance resembling elaterite was obtained. The nature of these oils and other bodies from these and similar experiments are discussed, and their bearing on the origin of the natural deposits considered.

In another series of experiments by the same author,[†] by distilling together fat, pine wood, and fresh herrings from the Delaware river, from an iron retort, and passing the vapours through a red-hot iron tube, there was produced water and an oil of specific gravity 0·9837 containing 84·28 per cent. of carbon and 10 per cent. of hydrogen. After distilling the oil up to a temperature of about 425°, a residue was left in the retort, which solidified to a black, shining mass, showing conchoidal fracture, brittle, and pulverising to a brownish-coloured powder slightly darker than the powder of the natural asphalt "gilsonite" from Utah, which it closely resembles. The analysis of the two materials gave the following figures:—

| | C. | H. | N. | S. | O. | Ash. |
|---|---|---|---|---|---|---|
| **Artificial** . . | 86·56 | 7·06 | 1·91 | 0·08 | 4·39 | ... |
| **Natural** . . | 85·83 | 10·59 | 2·59 | 0·26 | 0·63 | 0·10 |

---

[*] *Journal of the Franklin Institute*, vol. cxlviii. pp. 205–239.

[†] *American Chemical Journal*, vol. xxi. pp. 478–499; *Journal of the Chemical Society*, vol. lxxvi. pp. 559–561.

R. Zuber* discusses the several modern hypotheses respecting the origin of petroleum, but does not endeavour to propound a new theory. Very numerous references are given to the literature of the subject. The so-called emanation or distillation and condensation theories are considered to be untenable, but the various organic theories are considered at length, much attention being given to the influence of geological data.

**Petroleum in Russia.**—The island of Tscheleken lies on the eastern side of the Caspian Sea, and on it petroleum is found. From time immemorial the inhabitants of the island have won the oil. They sink wells to a depth of about a couple of fathoms and then ladle the oil out. Although a number of boreholes have been put down, and these have proved productive, but little has yet been done on any scale. The oil is stated by Sokolawski and Charitschkow † to bear considerable resemblance to Pennsylvanian petroleum. The petroleum having the density of 0·795 and a boiling-point of from 160° C. to 300° C., is almost identical with the American oil, but the yield is but slight, amounting to only 22 per cent. from oil having the specific gravity 0·8686. The Tscheleken petroleum is not suited for the preparation of lubricating oil, but it contains valuable constituents, such, for instance, as from 5 to 5·5 per cent. of paraffin. In consequence of this high percentage of paraffin the raw oil solidifies at 2° C. At 9° C. it looks like a lubricating oil. The residues from the Tscheleken oil are entirely different from the masut residue of the Baku oil. They resemble much more closely the unrefined vaseline from the American petroleum. After treating them with sulphuric acid and caustic soda and filtering through bone charcoal an excellent vaseline is obtained which can be used for perfumery purposes. In addition to petroleum, hot springs rich in dissolved sulphate are also met with on the island. One of these has a temperature of 53° C.

A detailed account has been published of the pipe line for transporting petroleum from Michailova to Batoum, a distance of 138 miles. The installation comprises three stations at Michailova, Ssamtredi, and Ssupssa, each with two 150 horse-power pumping-engines. The oil is pumped into a sheet iron pipe 7·8 inches in diameter. The usual amount passing through is 90 tons of oil daily. The maximum output contemplated is 25,000 tons of oil per year. The pipes have been tested up to 120 atmospheres.*

---

* *Zeitschrift für praktische Geologie*, 1898, pp. 84–94; *Petroleum Review*, vol. i. pp. 343, 379.

† *Nephtenoje delo*, 1899, p. 217; *Zeitschrift für angewandte Chemie*, 1899, p. 378.

N. Cherkassov † deals with the use of petroleum fuel for vessels of the Russian navy and volunteer fleet, making various suggestions as to the supply and distribution. The oil resources of Russia and the nature of the residues from distillation, which are used for fuel purposes, are discussed, and their advantages are summarised.

**Petroleum in Roumania.**—D. A. Sutherland ‡ gives an account of the present condition of the Roumanian petroleum industry. The oil has been known in that country for over two hundred years, and for a long time has been obtained from dug wells, in a district some 300 to 400 miles long and 15 to 20 miles wide, on the fringe of the Transylvanian and Carpathian Alps. Within the last seventeen or eighteen years many drilled wells have been sunk, and have proved the oil at a depth of 1000 feet, while some wells have been sunk as deep as 1700 feet. The production of 1898 was about 150,000 tons, but no exact statistics are available; there appear to be about 80 productive boreholes, several companies being at work. Petroleum fields are found at Stoenesti, in the district of Valcea, Glodeni, Campina, Tega, Moinesci, and Solonti, after which they may be traced into Galicia. The fields on which most capital has been expended are in the district of Prahova, and comprise Campina, Bustenari, Recea, Baicoi, and Tintea. There are fully 800 hand-dug wells about five feet in diameter, ventilated by bellows, and mostly sunk in clayey or other soft strata lined with clay and wicker work. Drilled wells are sunk with modified Canadian rig, and are generally of too small a diameter. Brief descriptions are given of the various fields, and economic and other questions are discussed. A large number of photographic illustrations are given, and a sketch geological map of the country is appended.

K. A. Redlich § observes that petroleum exists in considerable quantity in Roumania, but it is not yet mined to the extent the deposits deserve. Only eighteen undertakings are properly equipped with machinery, and machine boring has been but little employed. The chief portion of the petroleum has been obtained from wells sunk by hand, and skilled management is usually absent.

---

* *Praktische Machinen-Constructeur,* August 31, 1899. See also the *Petroleum Review,* vol. i. pp. 126–127.

† *Morskoi Sbornik,* July 1898, p. 129.

‡ *Petroleum Review,* vol. i. pp. 95–101 and 131–137. Reprinted as a pamphlet, pp. 46.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen,* vol. xlvii. pp. 174–175.

The author also refers to the brown coal deposits of Roumania. The Government has proved these in a large number of places. The seams examined have usually exceeded 16 feet in thickness, and the industry is likely to become one of great importance for the country. At present some 63,000 tons of brown coal are mined in Roumania annually.

The Roumanian oilfields are also described by Hans Urban,* and also in a report to the Foreign Office from the British Acting Consul-General at Galatz.†

**Petroleum in Canada.**—H. M. Ami ‡ describes a new or hitherto unrecognised geological horizon in the gas and oil regions of Western Ontario, Canada. The formation is of marine origin, overlying the Kettle Point shales, and consists of fine-grained, calcareo-argillaceous pyritiferous shales. The discussion turned on the Trenton formations and the preservation of records of borings.

**Petroleum in California.**—W. L. Watts § publishes some notes on the oil-yielding formations of California, and also a portion of a report to be published by the State Mining Bureau, in which he gives information of the value, geological features, and depth affected.

Harold W. Fairbanks ‖ has published some notes on the petroleum deposits of California, describing the conditions under which petroleum occurs in California. They seem not to be in accord with Professor Orton's statements concerning Eastern fields.

**Petroleum in Colorado.**—Arthur Lakes ¶ has published an article on prospecting for oil in an untried region, in which he points out how oil was found in Colorado, where there were no direct indications on the surface.

**Petroleum in Japan.**—Shiu-ichi Takano ** reviews the history of the petroleum industry in Japan, which practically dates from 1866, though oil had been known since 674 A.D. It is found in all parts of the country, but the leading districts at present are Echigo, Totomi, Ugo, and Shinano. Over 85 per cent., however, is produced in Echigo.

---

* *Organ des Vereins der Bohrtechniker*, 1899, No. 13.

† *Colliery Guardian*, vol. lxxviii. p. 789.

‡ *Journal of the Canadian Mining Institute*, vol. ii. pp. 186-191 and 207-211.

§ *Mining and Scientific Press*, August 5, 1899.

‖ *Ibid.*, May 20, 1899.

¶ *Mines and Minerals*, vol. xix. pp. 477-478.

** *Petroleum Gazette*, through the *Petroleum Review*, vol. i. pp. 446-475.

Particulars of the geological structure of the districts and of the shafts and wells are given, with some statistics.

**The Use of Petroleum in the Manufacture of Sheet Iron.**—P. Kosakevitz* describes the use of petroleum residues as fuel in the manufacture of sheet iron at the Nytvinsk factory of the Kamsk Company. The construction of the heating furnace is generally similar to that of a gas-fired furnace, only the oil is introduced by a sprayer, which is movable so as to direct the flame over any part of the hearth. Heat can be raised very rapidly, and the ingots are uniformly heated without wasting by oxidation. The weight of oil used amounts to 4 per cent. of the ingots treated, but might be reduced by heating the air. After rolling, the sheets are heated and hammered to improve the surface, and for annealing.

**Tubes for Boring.**—In 1895 a committee was appointed to consider the subject of uniformity in the sizes of lining tubes and their joints. The results of the investigations are given by W. Wolski.† A series of sizes are suggested, giving diameter and thickness of tube. Screw joints with coned threads are recommended, and the thickness of the walls is preserved by expanding or contracting the diameter at the joints.

**Petroleum Motors.**—In a lengthy monograph Dopp ‡ considers the question of petroleum motors, and devotes special attention to those recently devised by Diesel and by Dopp.

J. Körting § briefly refers to the Diesel petroleum motors, which resemble, he says, vertical steam-engines, and work very smoothly. Nothing further has appeared with reference to the use of gas in these motors.

**Petroleum and its Flashing-Point.**—E. Přiwoznik || observes that the great danger of raw petroleum taking fire is mentioned in the very earliest descriptions. It is first mentioned by Eratosthenes. The

---

* *Russian Mining Industry*, through the *Petroleum Review*, vol. i. pp. 347–348; with illustrations.

† *Naphtha; Petroleum Review*, vol. i. pp. 206–212.

‡ *Verhandlungen des Vereines zur Beförderung des Gewerbfleisses*, pp. 140–154; one illustration.

§ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xliii. p. 554.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 301–303, and 316–318.

Talmud requires that white naphtha, on account of its liability to take fire, shall in particular not be used on the Sabbath. Reference is made to various ancient authors as mentioning the existence of petroleum and describing its properties. Whatever the place at which it is found, raw petroleum is always a mixture of hydrocarbons, whose specific gravities and boiling-points vary greatly. In particular, petroleums which belong to the methane series, $C_nH_{2n+2}$, contain constituents which either escape from the oil direct, or do so on its being slightly heated. When these escaping hydrocarbons are mixed in a closed space with air, mixtures are formed which the least spark will explode.

The Pennsylvanian oil is especially dangerous on this account. The danger attending its use was soon recognised, and refineries were erected. Most of the raw petroleums found cannot be used direct as illuminating agents on account of this danger from explosion, or else they are too thick-fluid for use in this way. Almost all require to be submitted to fractional distillation, and subsequent treatment of the distillate by sulphuric acid and caustic alkalies. In this way products are obtained which are less dangerous than the original oil, while others are also produced which are, on the other hand, of a more explosive character. The products of the fractional distillation of raw petroleum are as follows:—

| | Boiling-Point. Deg. C. | Density. |
|---|---|---|
| Petroleum ether | 15 to 100 | 0·65 to 0·70 |
| Benzol | 100 „ 120 | 0·70 „ 0·73 |
| Machine oil | 120 „ 150 | 0·73 „ 0·75 |
| Illuminating oil | 150 „ 300 | 0·75 „ 0·86 |

In addition there is tar, amounting in quantity to from 5 to 10 per cent. of that of the original oil. From this tar lubricating oils are obtained, and by repeated treatment with concentrated and even fuming sulphuric acid the very valuable product vaseline is produced. This also consists chiefly of hydrocarbons. The author deals separately with the various distillates above mentioned, and in particular with illuminating oil. If the percentage of light oils in a petroleum—of oils, that is, with a boiling-point below 150° C.—does not exceed five, the flashing-point is still adequately high to render the oil of use as a commercial illuminant. Finhener has shown that petroleums are on the market which contain hydrocarbons whose boiling-points are higher than 340°. The author gives the results of the fractional distillation of various kinds of commercial petroleum as sold for illuminating purposes.

## VI.—*NATURAL GAS.*

**Natural Gas in Ontario.**—In Welland peninsula, Ontario,* the number of wells bored is 124, of which 65 are producing gas, but the pressure has fallen from 520 lbs. to 175 lbs. per square inch. When the pressure in a well falls to 70 lbs. it is pumped dry and plugged. In some cases gas is pumped into wells which have been large producers, as they then act as reservoirs. The gas is piped to Buffalo, but probably in a few years the supply will become so small that it will be restricted to more local use.

**Natural Gas at Athabasca Landing.**—W. A Fraser † states that a boring was put down at Athabasca Landing in Northern Alberta to a depth of 820 feet in search of oil, but was stopped by the great flow of gas, which has been very persistent. Owing to the cooling due to expansion, the boring has been partly choked by the deposition of a solidified mass of maltha, and this is very difficult to remove. Further attempts were made to reach the "tar sands," but owing to the caving nature of the shales passed through, together with difficulties due to some very hard layers, the borings were not successful.

**Natural Gas in Colorado.**—Arthur Lakes ‡ has published an article on the natural gas in Colorado, in which he deals with the origin of natural gas and petroleum, and their relations to bituminous shale and asphaltum, and also describes the White River gas field.

**Natural Gas in Indiana.**—Further extensions of the pumping plant for supplying Chicago with natural gas from the Indiana field have been made.§

**Natural Gas in Virginia.**—The first report of the West Virginia Geological Survey has just been published. It covers 392 pages, and has been drawn up by I. C. White, the State geologist, who contributes a practical report on petroleum and natural gas.

---

* *Geological Survey of Canada, Annual Report*, vol. ix. pp. 121–122 A.

† *Ibid.*, vol. ix. pp. 13–18 A.

‡ *Mines and Minerals*, vol. xix. pp. 339–340.

§ *Iron Age*, June 29, 1889, p. 3.

## VII.—*ARTIFICIAL GAS.*

**Gas-Producers.**—J. Douglas[*] describes the gas-producers used in Sweden to gasify sawdust, shavings, bark, and all waste wood which is too small to be converted into charcoal. The bed is 12 feet deep if air can pass, but with sawdust it is reduced to 6 feet. The moisture and tar are sometimes condensed, but this is not necessary, and the crude gas is very generally used, especially when the fuel is first dried. The producers work without grates, as there is no clinker and very little ash. Forced draught is used when the producers are charged with sawdust. Sections of the producer are given. Reference is made to the waste of refuse wood in Canada as a contrast.

A. Lencauchez[†] has published an exhaustive paper on various combustible gases used principally for power production.

**The Dellwik Gas-Producer.**—It is stated by H. Dicke[‡] that the Dellwik gas-producer will give 40 cubic feet of water-gas per pound of coke, as compared with half that amount by the old water-gas process. Waste gas consisting of carbonic anhydride and nitrogen is produced during ten minutes, and for fifty minntes the gas consists of carbonic oxide and hydrogen, as the temperature is maintained at 1000° C., when carbonic anhydride is completely reduced to carbonic oxide in the presence of carbon.

**Improvements in Producer Gas.**—Frank[§] draws attention to the use of air containing a heightened percentage of oxygen in the manufacture of producer gas. By means of the Linde apparatus it was stated that the percentage of oxygen in the air used could be increased by one-half, and that, too, at very small cost. Still but little seems to have so far been done in this direction in practice. The author points out that a further improvement would consist in the combustion with this enriched air of the gas prepared in the manner recently suggested by Hempel. This consists in making a mixed gas by blowing through red-hot coke a mixture of steam and of air enriched in oxygen by the Linde method.

---

[*] *Journal of the Canadian Mining Institute*, vol. ii. pp. 38-53.

[†] *Mémoires de la Société des Ingénieurs Civils de France*, vol. lii. pp. 776-865.

[‡] *Dellwick-Fleischer's Wassergas System und seine Anwendungen*, Pamphlet, July 1899, Frankfurt; *Zeitschrift des Vereins von Gas und Electricitäts und Wasserfachmännern Rheinlands und Westphalens*, April 15; *Progressive Age*, vol. xvii. p. 395.

[§] *Stahl und Eisen*, vol. xix. pp. 644-645.

## VIII.—*COAL-MINING.*

**Deep Boring.**—The Thirteenth International Congress of Engineers engaged in deep boring was held in September 1899.* In a presidential review of the progress of boring, Pinno pointed out that the borehole, 1851 yards deep, completed at Strassfurt in 1851, took twelve years to finish, whilst recently the borehole at Paruschowitz reached a depth more than three times as great in a sixth of that time. The first paper was read by E. Przibilla of Cologne, and dealt with the use of compressed air in boring. He urged the importance of improving the screw-threads of boring rods. For this purpose he had devised a method in which the rods were thickened at the ends. He advocated the use of compressed air in boring for petroleum, as all danger of fire was obviated. Experience in France showed that the air compressor might be placed a couple of miles away from the borehole. Fauck then described the salient features of the system of boring bearing his name, and Paul Lange gave an account of the rock drill invented by him, in which the drill was made to advance by hydraulic power, whilst its working was effected by electricity. The boring crown is set with Brazilian diamonds, and the drill makes about 1500 revolutions a minute.

In a borehole 300 yards deep, put down at Ostroppa by the Upper Silesian Deep Boring Company, the cap of a borer broke off.† Further boring became impossible, as the fragments of steel at the bottom of the hole cut the diamond crown. After various attempts to remove the steel fragments, a steel magnet, 5 feet long and 2¾ inches in diameter, was constructed. It was wound round with a single layer of insulated wire, and magnetised by the current from a small dynamo driven by the portable engine used for boring purposes. The magnet was lowered in an unmagnetised state, and when it touched the bottom of the hole the current was switched on. On the first day the steel fragments were successfully raised and boring operations resumed.

W. J. Cousins‡ describes the operations for the recovery of the Ropersole borehole, Kent, in which the rods had broken at a depth of 1544 feet from the surface, and could not be withdrawn. At this point the boring was carried on to one side with a gentle slope, and has now been sunk to a depth of 1740 feet.

---

* *Glückauf*, vol. xxxv. pp. 784–785.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlvii. p. 209.

‡ *The Bullionist*, October 7, 1899; *Iron and Coal Trades Review*, vol. lix. p. 657.

**Shaft Sinking.**—A. Demeure [*] describes the opening of a new seam at the Bois-du-Luc collieries in Belgium. For this purpose a shaft was sunk by means of the Kind-Chaudron process, and several important improvements were introduced with a view to saving time. Léon Thiriart [†] describes the methods adopted at the Patience and Beaujoue collieries for obviating the occurrence of accidents in shafts.

Vrancken [‡] publishes an article on the iron lining of a shaft for catching the water, in which he describes the manner of overcoming the incursion of water in the winding shaft.

F. Schulte [§] publishes an article on repairing the tubbing of Shaft No. 1 of the Gneisenau mine at Derne, and describes the manner in which the cast-iron lining of the shaft was reinforced by an inner lining for a portion of its length.

R. Clive gives a detailed description of tubbing shafts against water.[||]

W. Galloway's series of lectures [¶] on mining includes one on sinking, and deals with drilling, winding, tubbing, and generally with the whole subject.

The deepest vertical shaft in Canada is sunk at the Albion Colliery of the Acadia Coal Company at Stellarton, Nova Scotia. Its present depth is over 900 feet. The longest working incline is at the Drummond Colliery, Westville, Nova Scotia, the present length of which is over 5000 feet.[**]

De Serres [††] describes the movable platform used for lining the St. Louis shaft at the St. Etienne Collieries.

**Winding Appliances.**—H. W. Martin [‡‡] discusses the problem of winding in deep shafts, making special reference to balance ropes and conical drums.

The following are the main features of the winding machinery adopted by the author at a new colliery in South Wales, with the view of raising from two shafts a large daily output:—The pressure of steam at the boilers is 100 lbs. per square inch; the shafts are each 740 yards deep and 20 feet diameter in the clear; the useful load is 5 tons; the cages weigh 5 tons each; the pithead pulleys are 18 feet in diameter, and each weighs 5 tons; the trams are 12½ cwts. each, and there are two full trams raised tandem fashion, and two empty trams lowered each wind; each cage is guided in the shaft by four steel wire-rope conductors 1¾ inch diameter, weighing 19½ lbs. per yard, or 6 tons 13 cwts. per guide rope, loaded at the bottom end by a dead weight of 7 tons; two division or rubbing ropes, 2¼ inch diameter, hang between the cages to prevent them colliding when passing each other, and each weighs 29 lbs. per yard, or 9 tons 15 cwts., and is weighted at the bottom with a load of 10 tons. Thus far the arrangements of the two shafts are identical.

---

[*] *Annales des Mines de Belgique*, vol. iv., pp. 465–486.

[†] *Ibid.*, pp. 487–514.

[‡] *Colliery Guardian*, vol. lxxvii. p. 1101.

[§] *Glückauf*, vol. xxxv. pp. 525–527.

[||] Prize Essay of the British Society of Mining Students.

[¶] *Proceedings of the South Wales Institute of Engineers*, vol. xxi. Appendix.

[**] *Canadian Mining Review*, vol. xviii. pp. 165–166.

[††] *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 141–143; with plate.

[‡‡] *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxxviii. pp. 422–425.

The winding engine at the south pit has two horizontal cylinders, each 36 inches in diameter by 6 feet stroke, and is non-condensing, and has a plain cylindrical drum 17 feet 6 inches in diameter, weighing without the shaft 35 tons. Arrangements are being made for fitting this engine with an automatic expansion gear. The winding ropes are of untwistable flattened strand, 1¾ inch diameter, weighing 20 lbs. per yard. A balance rope, slightly exceeding in length the winding depth of the pit, and of an equal weight per yard to that of the winding ropes, is attached under the cages.

The winding engine at the north pit has two horizontal cylinders, each 42 inches in diameter by 7 feet stroke. It is non-condensing, and has a conical drum for eleven coils, and is afterwards cylindrical, weighing without the shaft 75 tons. The smaller diameter is 17 feet, and the larger 32 feet. This engine is fitted with an automatic cut-off gear. The winding ropes are locked coil 1¾ inch diameter, weighing 22 lbs. per yard.

At both pits the loading and unloading of the cages on the surface and underground is performed automatically by suitable locking and releasing gear in eight seconds or less.

T. A. O'Donahue * describes the endless-chain winding plant at Rowley Colliery, near Burnley. The chains are made from wrought iron bars 1 inch by ½ inch in section, bolted together to form links of 14 inches in length between centres. There are two endless chains, having a total weight of 5 tons, and these pass over two vertical driving wheels 5 feet in diameter fitted at the top of the shaft. They are driven by a pair of vertical engines with 12-inch cylinders and 2 feet stroke, working with a steam pressure of 45 lbs. at the boilers. At present about 300 tons daily are raised from a depth of 90 yards. The writer does not consider any

---

* *Proceedings of the South Wales Institute of Engineers*, vol. xxi. pp. 215–222.

arrangement of endless chain applicable to depths greater than 300 yards.

One of the course of lectures published by W. Galloway [*] on winding deals with winding generally, and includes the various details of plant, head-gear, laying out the pit eye, &c.

H. W. Miller [†] advocates winding in stages from very deep shafts, and discusses the cost and advantages of winding in three stages from a shaft 6000 feet in depth.

An illustration has appeared [‡] of a tandem compound double-hoisting engine with flat rope drums for a Mexican mine with a shaft 2500 feet deep. The cylinders are 24 and 16 inches in diameter and 42 inch stroke.

W. Freakley [§] indicates the various forms of condensers used in connection with winding engines.

L. C. Morgenroth [||] describes various labour-saving devices in use at a Pennsylvania anthracite mine, including shaft fences, signals, &c.

Martinet [¶] describes the surface arrangements for sorting the tubs and the caging apparatus at the central shafts of the Commentry Collieries.

Sliding doors for mine cages at the Heinitz Colliery in the Saar district and at the Dechen Colliery near Saarbrücken are illustrated.[**]

Wire-rope conductors for pit cages are described by J. Vaughan.[††] The precautions necessary for their successful use are discussed, and then particulars are given of the size and quality of the ropes that should be used. The methods of placing them in position are also dealt with.

An article has appeared [‡‡] of the hoist equaliser of the Camphausen mine near Saarbruck, and a description is given of the ingenious method of counterbalancing the variable weight of the winding rope.

The Bley safety catch provided with teeth of different lengths, which, on a fall taking place, grip into the guides one after the other, those teeth which grip last being longer than those which first come into action. In this way a sudden stoppage is avoided, and, in one case where a rope broke, the total weight of two tons being lifted was stopped so gently that nothing more was required than to renew the rope before again lifting. Experimental results are given.*

---

[*] *Proceedings of the South Wales Institute of Engineers*, vol. xxi., Appendix.

[†] Paper read before the South African Association of Engineers, Johannesburg, May 13, 1899.

[‡] *Engineer*, vol. lxxxviii. pp. 320–321.

[§] *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 242–245.

[||] *Engineering and Mining Journal*, vol. lxvii. pp. 559, 589.

[¶] *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 168–170; with two plates.

[**] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlvii. p. 196.

[††] *Proceedings of the South Wales Institute of Engineers*, vol. xxi. pp. 200–214.

[‡‡] *Glückauf*, vol. xxxv. pp. 488–492.

Petit † describes the methods in use in the St. Etienne district for counterbalancing the cages used for lowering material for stowing. At several of the pits chains are now used, being attached to the bottom of the cage and to a point half-way down the shaft. The cage at the top of the shaft thus carries the full weight of a chain equal in length to half the depth of the shaft, and the cage at the bottom is free from the weight of the chain, but, of course, has the full weight of the winding rope.

**Steel Head Frames.**—George S. Binckley ‡ has published an article on steel head-frames for mines, in which he illustrates some types of frames, and points out their defects. He describes designs based on correct principles.

S. A. Everett § discusses the design and construction of pit-head pulley framings, and describes the construction of a head-gear built of T and C section iron to replace an old wooden framing. It was built with the legs splayed, and the back-stay much reduced in size as compared with ordinary practice. In fact, in view of the weight thrown on the vertical members by the wire rope guides, it became a question whether the back-stays might not be omitted altogether; but so radical a change was not ventured upon. The new frame was built alongside the old one and then moved bodily into place.

Illustrations of a number of colliery head-gears of rolled joint and lattice girder types have appeared. ||

**Winding Ropes.**—Statistics have been issued by the Dortmund Mining Bureau regarding the accidents with winding ropes that occurred at the collieries of the district in 1898. Out of 370 winding ropes

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 199.

† *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 21-32.

‡ *Mining and Scientific Press*, July 22, 1899.

§ *Proceedings of the South Wales Institute of Engineers*, vol. xxi. pp. 257-274; with illustrations.

|| *Iron and Coal Trades Review*, vol. lviii. pp. 683, 861.

discarded, two or 0·54 per cent. broke suddenly while in use. Out of the 6037 winding ropes laid aside during a period of twenty-seven years, from 1872 to 1898, the number that broke suddenly while in use was 260, or 4·28 per cent. of the ropes discarded. Breakages occurred in the case of 48 out of 826 flat cast-steel wire ropes, 19 out of 147 flat iron wire ropes, 7 out of 97 flat Manilla fibre ropes, 81 out of 4114 round cast-steel wire ropes, and 105 out of 881 round iron wire ropes, while not one of the eight hemp ropes gave way. It is satisfactory to note that the number of fractures tends to decrease. In 1872 the percentage of wire ropes breaking was 19·30, whilst in 1898 it was reduced to 0·54.*

Rodde † states that at the Montrambert Collieries the ordinary steel winding ropes are found to last so short a time, owing to the action of acid mine water, that they have been replaced by galvanised steel ropes. The latter have been found to answer very satisfactorily.

Ghysen ‡ has given a few notes on tests now in progress at the Marchienne and Marcinelle-Nord Collieries with winding ropes of uniform and decreasing section.

A statement has been published § of the depth of Belgian collieries and the nature of the winding ropes employed on July 1, 1899. The following shafts exceed 1000 metres (3280 ft.) in depth :—

| Colliery. | Depth. | Winding Rope. |
|---|---|---|
| | Metres. | |
| Agrappe No. 10 (Mons) . . . . | 1,010 | Flat aloe |
| Produits No. 18 (Mons) . . . . | 1,150 | ,, |
| Sacré-Madame (Charleroi) . . . . | 1,065 | ,, |
| Marchienne No. 1 (Charleroi) . . . | 1,058 | Flat steel |
| Marchienne No. 2 (Charleroi) . . . | 1,030 | ,, |
| Marcinelle Nord No. 11 (Charleroi) . | 1,080 | ,, |

**Underground Haulage.**—Some particulars are given by H. K. Meyers ‖ of the use of compressed air and of electric locomotives for underground haulage. Especial reference is made to the results obtained with combined battery and trolley electric locomotives. Notes are also given on the comparison of mule and electric haulage, and other illustrations of American electric locomotives have appeared.*

---

* *Glückauf*, vol. xxxv. pp. 621–623.

† *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 32–34.

‡ *Colliery Guardian*, vol. lxxvii. p. 1204.

§ *Annales des Mines de Belgique*, vol. iv. p. 662.

‖ *Proceedings of the Engineers' Club of Philadelphia*, July 1899 ; *Iron Age*, vol. lxiv., August 24, 1899, pp. 13–15.

An illustration has appeared of one of three compressed air mining locomotives built for the Yuburi coal-mine in Japan.† The locomotive runs on a track of 19⅝ inches gauge and its extreme width is 3 feet 3 inches. The extreme height is 4 feet 10 inches, and the length over all is 14 feet 10 inches. The cylinders are 6 inches in diameter by 10 inches stroke. There are four driving wheels, 22 inches in diameter, which are spaced 4 feet between centres, and carry the entire weight, 12,500 lbs.

The working pressure carried in the main tank is 800 lbs.; this is reduced by an automatic valve to a uniform pressure of 140 lbs. at delivery to the auxiliary reservoir, from which the air is distributed to the cylinders through a specially constructed throttle valve. This locomotive is also fitted with re-heater arrangement.

W. W. Clayton ‡ gives some notes on the construction and use of colliery locomotives.

J. Hersten § also deals with underground haulage by locomotives.

Electric haulage and hoisting, especially in the Witwatersrand, are discussed by J. W. Kirkland. ||

A special number of *Cassier's Magazine* deals with many of the features of electric traction, chiefly for street tramway work.

An illustration of an electric mining locomotive made by the Oerlikon Works, Zurich, has appeared.¶

At the Montvicq Colliery in France, according to G. Boutonnet,** a turbine driven by an underground feeder has been used to haul the coal up an incline rising 180 feet in its length of 470 feet. Illustrations of the plant are given.

**Electricity in Mines.**—J. P. Jackson and F. F. Thompson †† discuss the use of electricity in mines, especially in reference to the mining of soft coal. Of the essential elements in operating such mines, two of the most important are:—First, apparatus to obtain efficiently the rapid

---

* *Engineer*, vol. lxxxviii. p. 304.

† *Engineering and Mining Journal*, vol. lxvii. p. 623.

‡ *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 212–217.

§ *Annales des Mines de Belgique*, vol. iv. pp. 515–527.

|| Paper read before the South African Society of Electrical Engineers, through the *Iron and Coal Trades Review*, vol. lix. pp. 344–346.

¶ *Engineer*, vol. lxxxvii. p. 410.

** *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 172–174; with plate.

†† Paper read before the American Institute of Electrical Engineers, Boston, June 27, 1899.

handling of the coal; and, second, to do this with the least possible number of openings. These conditions have evidently been large factors in causing the application of electricity to such operations. The applications of power to mines which are considered are principally for (*a*) lighting, (*b*) haulage, (*c*) cutting or drilling, (*d*) pumping and driving fans. The systems worth considering which are in use at the present time may be tabulated as follows:—(1) Rope and steam haulage; (2) compressed air haulage; (3) electric haulage. Examples of these from various collieries in the United States are given.

H. S. Childe * discusses the comparative advantages of electricity, steam, and compressed air for mining purposes, especially for pumping, hauling, and coal cutting. He concludes that for general surface purposes steam is undoubtedly first; for working in shafts and for all underground work (excepting on the one ground of safety) electricity has the advantage over compressed air.

C. R. Buck † illustrates some of the applications of electricity for use in collieries. Questions of wiring, locomotives, coal-cutting machinery, and drills are considered.

W. Nowell ‡ gives details of the electric power plant used for hauling and pumping at the Haunchwood Colliery.

Goichot § describes the electric transmission plant at the Blanzy Collieries.

A description is published of the plant for the electric transmission of power that has been put up at the brown coal pit, Julius III., in the Brüx mining district. A central power-station has been erected, which serves for pumping, ventilating, lighting, and motive purposes. ||

Heise and Thiem ¶ give at considerable length the results of experiments made at Gelsenkirchen on the ignition of fire-damp and coal-dust by means of electricity. In conclusion, a number of recommendations as regards the use of electric lamps and motors for underground use are given.

Desvignes ** describes the three phase current system for the transmission of power at the Cros Collieries in the St. Etienne district.

---

* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxxviii. pp. 432–435.

† *School of Mines Quarterly*, vol. xx. pp. 224–250.

‡ *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 248–253.

§ *Bulletin de la Société de l'Industrie Minérale*, vol. xiii. pp. 179–204.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 461–463; with two sheets of illustrations.

¶ *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 88–116.

** *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 1–7.

**Coal-Cutting Machinery.**—H. F. Bain[*] describes the Lee longwall machine, which is one of the cutter-bar type electrically driven. The cutter-bar is of novel construction, consisting of a taper bar wound with a spiral band of tool steel with forty-two projecting teeth. The band is $2\frac{5}{8}$ by $\frac{3}{16}$ by 63 inches, and the bar tapers from $2\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter. The teeth are re-ground after cutting about 100 linear feet, and as they are spirally placed, they bring out the cuttings. The bar is driven by bevel gearing from the motor, and mounted so that it can be swivelled in and out of the coal. The ordinary work is 600 to 650 square feet undercut in eight hours, with two men and ten or twelve followers for loading and gobbing.

B. Parker[†] gives some notes on the use of the Hurd bar-cutter electrically driven machine at the Foxfield Colliery, on a face 1680 feet in length. The undercut is $3\frac{1}{2}$ feet deep, and tapers from 5 to 2 inches in height. The machine feeds itself by a rope fixed 180 feet in front, and is run by three men. The gates are 90 feet apart.

A heading machine with a bar-cutter, caused by a drag-link motion to follow an approximately square path, has been devised by C. Koerte and Isaac Atkinson. Illustrations of it are published.[‡]

W. D. L. Hardie[§] compares machine-mining and pick-mining as carried on in the Galt coalfield, Alberta, Canada, at the Lethbridge Colliery. The working is done on a pillar-and-stall system, with wide and with narrow stalls or entries, and the costs in the different forms are given, together with the cost of the plant.

The Sommer coal-cutter, which is being tried experimentally at the Langenbrahm Colliery, near Rüttenscheid, Westphalia, consists of two parallel boring tools spaced from 1 to 1·2 metre (3·28 to 4·9 feet) apart, between which a reciprocating cutter-bar is arranged transversely to them and driven by eccentric gear, so as to remove the coal between the boreholes.[‖]

E. W. Parker[¶] gives the statistics of coal-cutting machinery in the United States for the year 1898, as compared with the previous year:—

---

[*] *Transactions of the American Institute of Mining Engineers*, September 1899.

[†] *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 238-241.

[‡] *Colliery Guardian*, vol. lxxviii. pp. 635-637.

[§] *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 171-179; with plate.

[‖] *Colliery Guardian*, vol. lxxviii. p. 602.

[¶] *Transactions of the American Institute of Mining Engineers*, February 1899.

| | 1898. | 1897. | Increase. |
|---|---|---|---|
| Coal won by machinery, tons | 32,413,144 | 22,649,220 | 9,763,924 |
| Number of machines used | 2,622 | 1,956 | 666 |
| Number of firms using machines | 287 | 211 | 76 |
| Average tons mined by each machine | 12,362 | 11,572 | 790 |

These statistics are given as an appendix to the author's paper,* in which he gave, *inter alia*, full descriptions of a large number of machines, including the Harrison, Ingersoll-Sergeant, and Sullivan percussive pneumatic machines, the Morgan-Gardner electric percussive machine, the Sullivan shearing machine, the Jeffrey chain-breast machine, the link-belt or "Independent" machine, the Morgan-Gardner chain-breast machine arranged for shearing, and others. A short review of the patent history of coal-cutting machinery is also appended.

Ernest Kilburn Scott † has published an article on coal-cutting machinery from the humanitarian point of view, in which he gives a study of the subject, showing the superiority of machinery over hand labour, and the saving of life resulting from its adoption.

The thirteenth Annual Report of the Commissioner of Labour, covering 1604 pages, has been issued.‡ The report is the result of an investigation into the effect of the use of machinery upon labour and the cost of production. In the case of bituminous coal-mining the following results were obtained:—

| | Hand. | Machine. |
|---|---|---|
| Quantity mined | 100 tons | 100 tons |
| Year of production | 1895 | 1897 |
| Different operations performed | 11 | 13 |
| Different workmen employed | 93 | 60 |
| Time worked | 387 hours | 191 hours |
| Labour cost, dollars | 71·21 | 42·30 |

A similar comparison, made at another colliery in 1891 and 1897, gave the following results:—

| | Hand. | Machine. |
|---|---|---|
| Quantity mined | 100 tons | 100 tons |
| Year of production | 1891 | 1897 |
| Different operations performed | 13 | 15 |
| Different workmen employed | 42 | 32 |
| Time worked | 342 hours | 188 hours |
| Labour cost, dollars | 77·60 | 43·40 |

---

* See *Journal of the Iron and Steel Institute*, 1899, No. I. p. 345.

† *Electrical Review*, June 9, 1899.

‡ Washington: Government Printing Office, 1899. A copy of this report has been presented to the Institute Library.

**Explosives and Blasting.**—A new Home Office Order relating to explosives in coal-mines, dated July 27, 1899, repeals the two previous Orders, and embodies their contents, with some additions and alterations. Amongst the changes is the provision of certain safeguards in relation to the storage and use of detonators.

Some notes on the safe handling of high explosives have appeared.*

Further notes on safety explosives are given by W. J. Orsman,† with special reference to the accidents caused by handling explosives in the mine, and to the explosions of dust and fire-damp. A number of statistical tables are appended.

A paper on the use of permitted explosives has also been read by W. J. Orsman, ‡ and discussed.

L. T. O'Shea § gives some notes on the safety of modern mining explosives, with special reference to the methods of testing adopted in various countries.

The progress made in the manufacture of high explosives in 1898 is considered by Paul.‖ He briefly refers to various papers which have been published dealing with these, and to some new explosives. Amongst others he refers to liquid air.

A report by G. Chesneau ¶ to the French Fire-damp Commission deals favourably with the Davey-Brickford-Smith safety shot igniter. The fuse is provided with a cap and fired in a pistol device.

Further experiments have been made with liquid air as an explosive by the Austrian Technical Military Committee. The liquid air was mixed with solar oil and kieselguhr. The experiments showed that there was much loss of the liquid air during transport and use, the strength of the cartridges could not be guaranteed, and they had to be used very quickly after manufacture, so that many could not be fired together. Other points were also noted.**

In 1898 the Zauckerode Collieries finally abandoned the use of black powder.†† In addition to roburite, the new coal carbonite Nos. I. and II. were also introduced. These contain about 5 per cent. of potassium bichromate. Carbonite No. I. contains 25 per cent. of nitroglycerine, and No. II. 30 per cent. The roburite is found to answer very satisfactorily when in good water-tight cartridges. Carbonite No. II., in consequence of its higher percentage of nitroglycerine, is somewhat more powerful in character than No. I. Both, however, when compared with the older forms of carbonite, show a higher percentage of lump coal, and apparently also better gaseous products of combustion. Comparative experiments between the older forms of carbonite and roburite showed that the percentage of lump coal obtained was from 2½ to 3 per cent. higher with the roburite than with carbonite. The cost was about 50 per cent. above that of black powder, but the percentage of lump coal made was 2 per cent. less. Only electric firing methods are in use at the collieries of the Zwickau-Oberhohndorf Company.

---

* *Colliery Guardian*, vol. lxxvii. pp. 1059, 1134.

† *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 54-70.

‡ *Transactions of the Manchester Geological Society*, vol. xxvi. pp. 229-232.

§ *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 189-211.

‖ *Chemiker Zeitung*, vol. xxiii. pp. 667-669.

¶ *Annales des Mines*, vol. xiv. p. 567; *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 269-272.

** *Engineering*, vol. lxviii. pp. 304-305.

†† *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen*, 1899, p. 145.

Heise * discusses the progress made in electric blasting during the past two years. The manufacture of electric igniters has been rendered cheaper. The machines are simpler, lighter, and more trustworthy. Electric blasting is now as cheap as ignition by safety fuses, and the advantages it presents are such as to render its use highly desirable in all fiery mines.

**Methods of Working Coal.**—In a lecture on methods of working,† one of a series on mining, published by W. Galloway, the classification of Haton de la Goupillière is followed. In this system there are three main classes, depending on partial removal of mineral with abandonment of pillars and floor, complete removal of mineral while the roof is allowed to fall, and, third, complete removal of mineral and stowage. These classes are further subdivided, and examples of each are given in detail.

O. E. S. Whiteside ‡ compares the two methods of getting coal from breasts driven across the pitch in the direction of the strike, and from breasts at right angles to the strike under the conditions that obtain in the seams dipping at 30° to 50° in the Cretaceous measures at Anthracite and Canmore, North-Western Territory.

Havard-Duclos ‖ describes a new method of working the No. 6 seam at Lens, which is 30 inches in thickness, and dipping 15° on the average. Long stepped faces and complete stowing are used.

**Mine Drainage.**—In the long drainage adit which is being driven to connect the mines of Trets and Fuveau with the sea near Marseilles, driving by means of Bornet's electric boring machinery has been successfully adopted in the limestone. No timbering is required. A feeder of water with a pressure of 120 lbs. drives turbines and the dynamo for supplying power, light, and ventilation by a Mortier fan. Spoil is removed by an endless rope haulage. Work is carried on in three shifts of eight hours, and the average length driven in twenty-four hours was 18·60 feet, but as much as 22 feet has been driven. Two sets of shots are fired, as a rule, in each shift. Approximately twenty-four minutes are required for adjusting the machine in position, two hours for boring, twenty minutes for loading and firing, and the same time is required for smoke to clear. The removal of broken stuff takes an hour. Details are given of the number and length of boreholes, and of the consumption of drills.*

---

* *Glückauf*, vol. xxxv. pp. 437–443.

† *Proceedings of the South Wales Institute of Engineers*, vol. xxi., Appendix.

‡ *Journal of the Canadian Mining Institute*, vol. ii. pp. 17–20.

‖ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 112–127.

Stephen Michell † has published a second edition of his treatise on direct-acting underground steam-pumping machinery, in which all the leading classes and types are described. Since the publication of the first edition in 1881, the introduction of new types has gone on apace. The most noteworthy achievement during that period is the invention in 1884 by Professor Riedler of Berlin of the pump that bears his name, the salient feature of which is its mechanically operated water-valves. Mention should also be made of the D'Auria pump, a modification of the Worthington pump, as far as relates to the compensating principle of water-cylinders for storing up power at the beginning of the stroke, and dispensing it at the end; and of the Tipton compound pump, patented in 1897, in which the salient features are the position of the steam-chest and ports, which makes the engine self-draining, and the working of the high and low pressure pistons in one cylinder. Perhaps the most interesting developments have been the adoption of the American duplex principle for pumps, and the employment of electricity as a pump motor. Hydraulic pumps, another important recent introduction, are dealt with by the author in an appendix, which contains descriptions of the best known pumps of this kind—namely, those of Joy, used at the Clay Cross Collieries; of Davey, used at the Erin Colliery, Westphalia; of Moore, used at the Niddrie Collieries, Portobello; and of Kaselowsky, patented in 1894.

The construction and maintenance of pumping machinery formed a subject for discussion at a meeting of the Franklin Institute. The question of the cost of fuel, it was pointed out, was often the determining factor in the character of the pump. With cheap fuel, a high-duty pump would be bad engineering. With coal at 20 dols. a ton, as it is in some localities, a triple-expansion engine would be the proper selection. Such machines demand intelligent supervision, whilst the simpler double-action or even single-action pumps could be run with cheaper men and consequently with greater economy.

---

* *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1898, p. 179.

† "Mine Drainage." London: Crosby, Lockwood & Son. 1899.

W. M. Epton * describes the various systems for raising water from deep mines, including winding, the transmission of power by compressed air, hydraulic pressure, electricity, the use of underground engines and boilers, and of gas-engines.

George D. Rice † has published an article on the care of mining pumps, in which he considers the various things that cause trouble, and the means of remedying them.

Two photographic illustrations have been published ‡ showing the Riedler pump at the Powell-Duffryn Collieries, South Wales. The steam-cylinders are 36 inches and 57 inches in diameter by 48 inches stroke. The water-plungers are 6⅞ inches diameter by 48 inches stroke. The steam pressure is 90 lbs. per square inch. The steam-cylinders are jacketted and fitted with Corliss valve gear, and the pumps with Riedler's circular mechanically worked valve. The duty at 40 revolutions against a head of 1600 feet is 60,000 gallons per hour.

E. M. Hann § describes the Riedler pumping plant at the Elliot Colliery, New Tredegar, Monmouthshire. The pump is capable of delivering 60,000 gallons an hour against a head of 1600 feet when running at its normal speed. The pumps are duplex, and arranged in such a manner that either side alone should be capable of delivering the same amount of water, at, of course, double the speed, or at its maximum capacity. The steam pressure at the engine is to be a minimum of 90 lbs., the temperature of the water to be pumped 85 degrees Fahr. The pump considered most suitable for this work consisted of a horizontal cross compound Corliss engine with duplex pumps, driven from the tail piston-rod of engines, the speed of which should be 40 revolutions at its normal speed, and 80 when running one side only. Jet condenser and air pumps are arranged at the back of each main pump. The high-pressure cylinder is 36 inches in diameter by 48 inch stroke. The low-pressure cylinder is 57 inches in diameter

---

* Paper read before the *Johannesburg Mechanical Engineers' Association*.

† *Mining Reporter*, April 13, 1899.

‡ *Iron and Coal Trades Review*, vol. lix. p. 295.

§ *Proceedings of the South Wales Institute of Engineers*, vol. xxi. pp. 248–256; with two plates.

by 48 inch stroke. The main pump plungers are single-acting, outside-packed, 6⅞ inch diameter, there being four plungers and four sets of suction and delivery-valve chambers. The back and front pump plungers are connected to each other by side rods. Special arrangements are made for taking up the strains, and for making all the parts accessible, and of these a full description is given. Analyses of the water, which varied in composition from time to time, are given.

The use of oil-engines as pump motors underground is discussed by George L. Kerr,* and the cost as compared with steam is given to show the saving. With care in starting and in handling the oil, there is no danger in the use of oil-engines.

H. Dubbel† describes some new pumping engines at Silesian mines. Where the nature of the rock is such that rooms for engines can easily be hewn out, and where the depth is not too great, underground steam pumps are recommended, notwithstanding the disadvantage that the shaft is heated by the steam pipes. Hydraulic pumping engines may advantageously be used when very variable quantities of water are encountered, whilst special advantages are presented by the electric transmission of power for pumping engines, in that several engines at different points may be driven simultaneously. The author gives dimensioned working drawings of the pair of pumping engines installed at a depth of 340 yards in the Königin Luise mine at Zabrze, of those installed at a depth of 160 yards at the Giesche mine at Schoppinitz, and of those at the Karsten mine installed at a depth of 370 yards.

At the Ettes Colliery near Salgó-Tarján in Northern Hungary a new compound pumping engine has been placed underground. This is described and illustrated by S. Steuer.‡

G. E. J. M'Murtrie§ describes a self-filling and discharging water barrel for use in sinking pits, &c. It is provided with the usual inlet valve at the base, and contains a loose piston which is drawn up by the winding engine before the barrel is raised, thereby sucking up the water.

Illustrations have appeared‖ of Tomson's water-raising apparatus used in sinking the Minister Achenbach shaft near Mengede. The water is lifted by suspended pumps into a reservoir from which it is wound in barrels.

---

* *Colliery Guardian*, vol. lxxviii. pp. 638-639.

† *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. pp. 1093-1100.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 341-344; with sheet of illustrations.

§ Paper read before the British Society of Mining Students.

‖ *Glückauf*, vol. xxxv. pp. 389-390.

At the Auguste Colliery, near Morl, in the Westlich-Halle district of Germany, an elevator or chain of buckets has been introduced in order to raise the water, which is only small in quantity, from one level to another level which is 11 feet 6 inches above it.*

Petit,† and also Gerand,‡ describe in some detail, with the aid of maps and sections, some of the work that has been carried out in the St. Etienne district for the purpose of dealing with surface water by canalising the brooks and watercourses.

**The Ventilation of Collieries.**—J. T. Beard § discusses the design of fans chiefly from a mathematical aspect.

A. Rateau ‖ gives the results of some experimental investigations on the Pitot tube and the Woltmann mill, showing that both pressure gauges and anemometers give good results in regular currents, but the indications are complicated when the speed varies irregularly. A translation by H. Louis ¶ of this paper has also appeared.

D. Murgue ** describes his recording volumetric anemometer, in which a straight and a Pitot tube are joined to a differential pressure gauge of special construction, which is arranged to give an autographic record of the static pressure of the air current.

In a note on the theory of fans, S. Hanappe †† deals with the application of Bernouilli's theorem to the motion of air between fan vanes.

An article has been published by Stens ‡‡ on the errors in fire-damp control, in which he discussed the proper method of mine ventilation to prevent the accumulation of fire-damp.

P. Fuchs §§ publishes an article on determining the velocity of ventilating air currents, in which he describes the mode of calculation and illustrates an instrument for carrying out these measurements.

---

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlvii. p. 187.

† *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, p. 45-54.

‡ *Ibid.*, pp. 65-72.

§ *Mines and Minerals*, vol. xx. pp. 54-56.

‖ *Annales des Mines*, vol. xiii. p. 331.

¶ *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 124-163.

** *Ibid.*, vol. xvii. pp. 261-268.

†† Communication to the Société des Ingénieurs des Mines du Hainaut.

‡‡ *Glückauf*, vol. xxxv. pp. 415-420.

§§ *Zeitschrift für Berg-, Hutten- und Salinenwesen im preussischen Staate*, vol. xlvii. pp. 73-78; *Colliery Guardian*, vol. lxxviii. p. 252.

H. Dehnke* has published an illustrated article on the best arrangement of ventilators to enable the utilisation of the entire shaft section, in which he shows the arrangement of head works to offer the least obstruction to ventilation.

W. G. Mixter † has published an article on a hypothesis to explain the partial non-explosive combination of explosive gases and gaseous mixtures, in which he reviews investigations made, and states his views, based on a study of the phenomena of explosives.

A course of lectures by W. Galloway ‡ on mining is being published. That on ventilation deals with the subject generally, and gives an account of the different forms of fans now in use.

Kette § publishes an article on forced ventilation plants, and gives the relative merits of forced and exhaust ventilation for mines. The use of underground blowers to force the air out of the mine is advocated.

At the Bolko shafts of the Fuchs Colliery, near Waldenburg,|| the air is exhausted from the shaft by means of two Pelzer fans each 10 feet in diameter. Either fan can be shut off from the shaft by lowering a counterpoised iron sliding door. The fans are driven by cotton ropes from the driving pulleys on the crank shafts of two 75 horse-power compound engines.

An interim report of the Victorian Mines Ventilation Board has recently appeared¶ dealing with 149 proposals made in response to the offer of a bonus of £1000, made by the Government for a satisfactory system of ventilating the mines in that country. It appears that no fan has been used in the colony, and a form of fan proposed by G. J. Massie has been taken into consideration.

Some notes on testing in connection with mine plants are given by K. Schweder.** The necessity of careful inspection of all parts and the use of reliable instruments is insisted upon.

**Fire-damp Outbursts.**—An outburst of gas at Westleigh Colliery is described by J. Gerrard.††

---

* *Glückauf*, vol. xxxv. pp. 638-640.

† *American Journal of Science*, vol. vii. pp. 327-334.

‡ *Proceedings of the South Wales Institute of Engineers*, Appendix, vol. xxi. One shilling.

§ *Glückauf*, vol. xxxv. pp. 541-547.

|| *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlvii. p. 203.

¶ *Iron and Coal Trades Review*, vol. lix. p. 659.

** Paper read before the Mechanical Engineers' Association, through the *Iron and Coal Trades Review*, vol. lix. p. 475.

†† *Transactions of the Manchester Geological Society*, vol. xxvi. pp. 162-170.

The instantaneous outbursts of fire-damp and coal at Broad Oak Colliery are described by John Gerrard.*

E. Van den Broek † discusses the correlation of earth tremors and fire-damp explosions.

**Fire-damp Detection.**—P. Fuchs ‡ deals with the continuous examination of pit gas for fire-damp by the Krell apparatus. The manometric difference of pressure between pure air and the pit air freed from carbonic acid is observed, and a continuous record is taken by photography.

Illustrations have appeared § of the testing gallery at the Maria Coal Mine at Höngen in the Aix-la-Chapelle district, and an account is given of the plant for testing the explosive character of mine gases.

**The Extinction of Fire in Mines.**—Several accounts have recently been given ‖ of the means employed for the extinction of fires in underground workings. At Hazelton, Pennsylvania, F. Pardee built a tank holding 6000 gallons at the mouth of the slope, with a gate large enough to let out the whole of the water at once. With about six tanks of water the fire was extinguished. At Alden Station, in the same State, K. M. Smith used dams to raise the water above the level of the fire, and describes the subsequent operations for recovering the mine. In an extensive mine he adds that the damage by water far exceeds that by fire. H. Burrell describes a fire at a colliery in Wyoming which was choked out by dry stoppings in the roads, and then by covering up the burning coal with soil when it could be reached.

Illustrations have appeared ¶ of a new method of mine flooding, in which a description is given of the method adopted by the Pennsylvania Coal Company for subduing a fire in their No. 6 shaft.

W. C. Morganroth ** has published an article on the burning mines of Summit Hill, in which he gives an account of the origin of the fire, and the conditions which have rendered efforts to extinguish it ineffectual.

---

* *Transactions of the Institution of Mining Engineers*, September 19, 1899.

† *Procès Verbaux de la Société Belge de Géologie*, vol. x. pp. 7-9.

‡ *Zeitschrift für Berg-, Hutten- und Salinenwesen im preussischen Staate*, vol. xlvii. pp. 73-78.

§ *Glückauf*, vol. xxxv. pp. 561-564.

‖ *Mines and Minerals*, vol. xix. pp. 539-540.

¶ *Ibid.*, vol. xix. pp. 465-466.

** *Ibid.*, vol. xix. pp. 441-443.

G. Spencer* describes the application of liquefied carbonic acid gas for the extinction of underground fires. In one case, a fire was stopped off and the contents of six bottles discharged into the space with successful results. The cooling result due to the expansion of the gas is considerable.

**The Lighting of Collieries.**—S. F. Walker† discusses the safety of the electric miners' lamp as compared with the ordinary miners' lamp, and traverses certain statements made on the subject by Halbaum. The liability of the filament to break before the glass in the case of larger incandescent lamps, and the small amount of power passing through the small lamps, render them very unlikely to ignite gas. The better light given by electric lamps also conduces to safety from falls of roofs and similar accidents.

S. F. Walker‡ discusses the question whether the portable electric miners' lamp should be worked with a primary or a secondary battery, and is of opinion that for the present single liquid primary batteries should be used.

Lafitte§ describes the Marsaut safety lamp, fitted with Sieppel's re-lighter and adapted for burning benzine. This lighter is one of those forms with a strip of caps.

**Rescue Appliances for Collieries.**—J. Mayer‖ describes arrangements for re-charging oxygen bottles used at collieries in connection with safety breathing appliances, and then discusses the results of practical experience with these in collieries. In a case he mentions the pressure in four oxygen bottles had been brought to the desired degree, and then arrangements were made to fill a fifth bottle. The same precautions were taken, but the bottle was soon noticed to become hot and sparks began to form about the valves, with the result that the metal melted. A violent explosion then took place with brilliant flames, and the whole of the oxygen of the bottle escaped. The whole thing happened within a few seconds. A similar case is also described. This, too, was followed by an explosion. The bottle fortunately did not burst, only the valve portions being destroyed. Investigations showed that these accidents were due to the material used to keep the valve air-tight. In the latter case a combustible material saturated with fat had been employed, and it is to the use of combustible materials for this purpose that such explosions are due. Fat, as is known, takes fire when brought into contact with oxygen under a pressure of 25 atmospheres. In bottles supplied by O. Neupert, the material used for the above-mentioned purpose was found to be pure asbestos, without any fat, held in place by two brass plates. These are not subject, of course, to dangers of this kind. To the author's personal knowledge numerous oxygen bottles with the faulty valve arrangements, such as those which led to the above-mentioned accidents, are still in use at various places.

---

* *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 181–185.

† *Colliery Guardian*, vol. lxxviii. p. 493.

‡ *Ibid.*, vol. lxxviii. p. 592.

§ *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 112–117.

‖ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 409–412, 427–430; with sheet of illustrations.

The author then briefly discusses various forms of safety breathing apparatus. In the case of the Walcher apparatus the arrangements for the nose and eyes are faulty, the latter especially. It was noticed that workmen being taught to use the apparatus were apt to keep their eyes tightly closed, as the fumes entered the apparatus around the eyeholes and their eyes were consequently not adequately protected. The author considers the Neupert mask as a distinct improvement on the Walcher apparatus, although the latter has had some considerable improvements effected in its construction.

G. A. Meyer * has published an article on rescue appliances in mines from a lecture delivered before the Verein der Technischen Grubenbeamten at Herne, in which he illustrates and describes the system in use at Shamrock Colliery.

The various rescue appliances for colliery use are described by Rössner.†

**Sanitation in Collieries.**—A pamphlet has been published dealing with the occurrence and prevention of the intestinal parasite *Anchylostoma* or *Dochmius duodenalis*, from which many Continental colliers suffer.‡

**History of Coal-Mining.**—A retrospect of the London coal trade has recently been published § in connection with the jubilee of the London Coal Exchange, which was built in 1847–51 out of duties levied on coal entering the metropolis. It was not until 1853 that the inland coal trade began seriously to compete with sea-borne coal, and until the repeal of the London coal dues, statistics were regularly published. In 1870 the inland duties realised more than the sea-borne duties for the first time, and some statistics are given to show the change. Numerous quotations are also given from a treatise on the serious evils resulting from the use of coal in the metropolis by the diarist Evelyn, entitled "Fumifugium, or the Inconvenience of the Aer and Smoake of London Dissipated, together with some Remedies humbly proposed to His Sacred Majestie (Charles II.), and to the Parliament now Assembled." Then the chief enactments affecting the London market passed since the reign of Queen Anne are reviewed.

---

* *Iron and Coal Trades Review*, vol. lviii. pp. 639–640.

† *Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines*, vol. li. pp. 459–462.

‡ *Iron and Coal Trades Review*, vol. lix. p. 716.

§ *Ibid.*, vol. lix. pp. 611 and 669.

The Dean of Westminster * draws attention to the old fireplace which breaks the eastern wall of the Jerusalem Chamber, Westminster Abbey. Externally there is nothing remarkable in it; it is not so picturesque as some of the open spaces in which wood fuel and charcoal were used. But it was one of the earliest sea-coal fireplaces used. Henry IV. was haunted by a constant fear of death from disease; and it was recorded of him that when very miserable he went to Bermondsey "for change of air." Probably he went there not so much for "air" as because of the Abbey, whose monks had a reputation of being able to cure leprosy. Henry was at the shrine of Edward the Confessor in the Abbey when he was taken with the fit which preceded his death, and for warmth he was brought in and laid before the coal-fire in the Jerusalem Chamber, and in "that Jerusalem" did Henry die.

F. Büttgenbach † gives an historical account of the mining for coal in the Aix-la-Chapelle district since the earliest times. Coal-mining is known to have been carried on in this field as far back as 1113. A seam was worked that outcropped about 65 yards above the valley of the Worm. The coal was first mined on behalf of the Augustine Abbey of Klosterrath, which formed a part of the old Duchy of Limburg. The records of the town of Aix-la-Chapelle showed that coal was being worked on behalf of the town in 1353, and was probably worked long before this date, as the first record gives proof of a distinct existing organisation. In those days running water and forest belonged to the State, and the same right was claimed for minerals obtained by deep mining. In 1353 a dialler was sent to Liége to purchase a better surveying dial, which incidentally shows that coal-

---

* *The Globe*, July 6, 1899.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 221-223.

mining had been carried on for some time in the Liége district also. In the sixteenth century the town of Aix-la-Chapelle allowed private individuals to mine for coal, retaining the right of supervision. Each colliery was obliged to have two open shafts and an "adoth" or water "adit," and in 1681 it was ordered that when one colliery was being worked, the adjacent workings of other colliery undertakings should not be interfered with. It was thought in those days that the coal would not last very long, and strict regulations were framed preventing all export from the territories belonging to the town. The Abbey, on the other hand, adopted an entirely different policy, and encouraged the exportation of the coal mined. In the Aix-la-Chapelle district no storing of coal was allowed, and the collieries were compelled to sell the coal only by donkey's burden or by the weight a man could carry, and the town authorities fixed the wages of the workpeople and the price at which the coal was sold. The Abbey, on the other hand, built roads from the collieries far out into the adjacent country for the purpose of facilitating transport. Other details are also given, and it is mentioned that even before 1600 the miner's working day had been fixed at eight hours. Swearing in or about the mine was forbidden, but not outside its limits. The patron saint was St. Catherine Mine surveying was evidently, even in early times, considered of much importance, for at the commencement of the sixteenth century the town authorities determined on the purchase of "compasses with a movable needle" for the more perfect dialling of the underground workings. In 1602 the miners worked in eight-hour shifts, the coal being drawn to surface by horses, and the water by a pumping appliance.

In connection with the statement that the first colliery working in Europe was in the neighbourhood of Aix-la-Chapelle, F. Büttgenbach * points out that in the same neighbourhood, in the Geule valley, and near Maestricht-on-the-Maas, there was a still older mining industry. This is still in progress near Valkenburg on the Geule, where building stone is obtained by underground working. This stone was mined by the Romans.

**Mine Surveying.**—A sample of a set of instructions regarding the preparation of American colliery plans is published.† All mine survey notes and plans should, it is pointed out, show meridian lines in squares of 1000 feet side, outlines of all workings and pillars, and survey lines and numbered stations. Postings of surveys at faces of workings should have dates and reference to notebook. Surface indications (watercourses, mine openings, outcrops) and boreholes should be shown, and elevations in relation to sea level should be noted. The thickness of the coal mined out should be marked occasionally on plans, and sections of the seam should be taken at intervals. Faults, falls, water, and other troubles should be described and noted on the plans. Careful use should be made of the record books and plans to keep them as free from wear and tear as practicable.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 534.

† *Mines and Minerals*, vol. xx., p. 78.

T. L. Carter * gives some hints on the kind of lights most useful for mine surveying. When sighting on to a string, a piece of tracing cloth is held between the string and the candle so that it can easily be seen in the diffused light.

**The Economics of Coal-Mining.**—Among recent papers of economic importance is one on the rating of coal-mines by George Humphreys-Davies.†

G. Johnson ‡ deals with the balance-sheet of a mining and manufacturing company.

Colliery invoices and the purchase of colliery stores and materials are dealt with by G. Johnson.§

**Collieries in Great Britain.**—Detailed descriptions have been published in the *Colliery Guardian* of a number of British collieries. The list includes the following in the Yorkshire coalfield:—Glass Houghton (vol. lxxvii. p. 1183), Grimethorpe (vol. lxxviii. p. 64), Hoyland Silkstone (p. 106), and Fitzwilliam-Hemsworth (p. 495).

The collieries in the Durham coalfield described are:—Burnhope (p. 539), East Knowle (p. 591), Tudhoe (p. 634), and Wheatley Hill (p. 684).

**Colonial Collieries.**—Harrison F. Bulman ‖ has published an article on the coal-mining in the colonies, in which he gives a summary of the present condition and extent of coal-mining in Canada, Australia, and New Zealand; an article ¶ on coal-mining in

---

* *Engineering and Mining Journal*, vol. lxviii. p. 214.

† Paper read before the Institution of Mining Engineers, September 19, 1899.

‡ *Iron and Coal Trades Review*, vol. lix. pp. 383–485, &c.

§ *Colliery Guardian*, vol. lxxviii. pp. 394–396.

‖ *Ibid.*, vol. lxxvii. pp. 749–750.

¶ *Ibid.*, vol. lxxvii. pp. 1187–1188.

British Columbia, in which he describes the collieries of Crow's Nest Pass and Vancouver Island; and an article * on the coal-mining in New Zealand, in which he gives information concerning the deposits, working, and Coal-mines Act.

An article on a Cape Colony coal-mine has been published,† with a statement of the conditions found by the writer at Indwe, in the north-eastern portion of the colony.

G. J. May ‡ gives details from actual practice of the cost of working coal in the Transvaal.

A description has appeared of the Great Eastern Colliery in the East Rand. An account of the screening plant is included. §

**Austrian Collieries.**—A. Fillunger || describes the Witkowitz Collieries, Dombrau. He observes that in the Ostrau-Karwin district a change in the relative degree of production is now observable, that of the eastern increasing relatively to the production of the western section of the field. This is due to the fact that the collieries in the western section are now being compelled to work thinner seams than heretofore. Of late considerable improvements have been introduced in the eastern section, modern plants having been laid down and older methods modified to suit present requirements. Various pits are referred to which have a modern equipment, and of all these the author considers that those at Dombrau are most likely to show the greatest production in the future. He describes these and their equipment, both above and below surface. The Bettina and Eleonoren shafts are at a distance of about 390 yards from each other in the centre of the property belonging to the Witkowitz Mining and Ironworks Company. These two shafts were old ones, narrow and timbered, but during the years 1893–97 the Eleonora shaft was taken in hand, greatly increased in size, and sunk to a depth of 604·5 yards, the timbering being replaced by iron and walling down to a depth of 491 yards. When this shaft was ready to wind, the Bettina shaft was taken in hand in a similar manner, and sunk to a depth of 469 yards. The costs for the various operations are given. The Eleonoren shaft is now 22 square yards in internal cross-section,

---

* *Colliery Guardian*, vol. lxxviii. pp. 105, 297.

† *Ibid.*, vol. lxxviii. p. 15.

‡ *Proceedings of the South Wales Institute of Engineers*, vol. xxi. pp. 99–104.

§ *Iron and Coal Trades Review*, vol. lix. p. 210.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 473–475, 487–489, and 499–502, with four sheets of illustrations.

and cost to sink per metre 270·85 florins for wages and 169·74 florins for material. The cost per metre for walling was 126·49 florins for wages and 243·50 florins for material. The total cost was thus about £67, 5s. per metre, or say rather less than £63 per yard. The two shafts are intended to wind about 650,000 tons as a maximum, and all winding arrangements and other appliances for the subsequent preparation and transport of the output have been arranged for on the basis of this maximum output. The author then proceeds to deal with the winding plants of the two shafts. These he describes in some detail with the aid of illustrations. At each shaft five tubs containing together four tons of coal are wound at once. Each shaft has two sections for winding, a large one and a small one, with separate engines.

The dry screening plant is centrally situated, and is intended to deal with an annual output of from 600,000 to 700,000 tons. The plant itself is described and illustrated. The plant for the electric transmission of power at the Eleonoren shaft is then dealt with and fully described.

Jičínský * describes the Heinrich Colliery at Karwin in Moravian-Ostrau. The winding shaft is walled, and is 17 feet 9 inches wide in the clear. It is divided into five divisions, one of which is a ladder-way, &c., the other four serving for winding purposes. The ventilating shaft is 12 feet 6 inches in diameter, and a Pelzer fan of 9 feet 10 inches in diameter, making 360 revolutions a minute, draws through it a current of air amounting in quantity to 105,950 cubic feet per minute. The colliery possesses a central electrical plant for power supply. This is described, as also are the other surface appliances of the colliery.

**The Zenica and Kreka Collieries, Bosnia.**—F. Poech † deals with the progress made by the coal industry of Bosnia in recent years, and describes the Zenica and Kreka Collieries. In the neighbourhood of Zenica four seams of coal are known to exist, three of which are large enough to admit of being won commercially. These have together a thickness of 46 feet of clean coal after deducting the partings. The seams strike south-east, and have been traced for a distance of about twenty-five miles. The coal is of Oligocene or Miocene age, and contains 2·6 per cent. of sulphur, and 6 to 10 per cent. of ash. It yields from 4600 to 5000 calories, and is a non-caking variety.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii.; *Beilage*, pp. 56-57.

† *Ibid.*, vol. xlvii. pp. 370-373; with plate.

Numerous faults render mining a matter of some difficulty. One such fault to the south causes a throw of over 260 feet, while another to the north twists the whole series of seams right round. The faults point to a lateral force having acted on the seams from a north-westerly direction. The difficulties thus experienced have naturally led to the output having been less than would otherwise have been the case, but still considerable progress has been made, as the following table shows :—

| Year. | Output. | Workpeople. | Per Man and per Shift. | |
|---|---|---|---|---|
| | | | Output. | Wages Earned. |
| | Metric Tons. | | Metric Tons. | Kreuzers. |
| 1880 . . . . | 500 | 16 | ... | ... |
| 1885 . . . . | 13,429 | 93 | 0·48 | 96·4 |
| 1890 . . . . | 6,385 | 61 | 0·50 | 100·1 |
| 1895 . . . . | 62,330 | 264 | 0·86 | 102·3 |
| 1898 . . . . | 103,700 | 364 | 1·14 | 107·6 |

Sixty kreuzers equal about one shilling.

The methods of mining employed at this colliery are described, as also are the colliery working arrangements. A Capell fan is in use. This is 6 feet 6 inches in diameter, and, with a velocity of 280 revolutions per minute, yields 28,250 cubic feet of air per minute, with a pressure of 1·8 inch of water. The number of men working in the colliery at one and the same time is 100. The fan is driven with rope-gearing by a 15 horse-power steam-engine. The separation processes to which the raw coal is submitted are also described.

At the Kreka Collieries near Tuzla, the coal deposits are known to extend for a distance of some nineteen miles. The main seam has a thickness of from 52 to 60 feet of clean coal, but is in places considerably thicker even than this. The working conditions as regards faulting are much better than those of the Zenica Collieries. No large faults occur, but numerous small fissures at bends have led to small fires. In connection with their extinction, experiments made by R. Sladeček with liquid carbon dioxide have been attended with success, but are not yet completed. The production at this colliery has increased from 9074 tons in 1880 to 160,000 tons in 1898, while the number of men employed has increased from 50 to 389. Details are given in the following table :—

| Year. | Output. | Workpeople. |
|---|---|---|
| | Metric Tons. | |
| 1880 | ... | ... |
| 1885 | 9,074 | 50 |
| 1890 | 52,219 | 128 |
| 1895 | 132,005 | 463 |
| 1898 | 160,000 | 389 |

The quantity of coal mined per shift and per workman in 1898 was 1·482 ton, and the wage earned 118 kreuzers, or nearly two shillings. The ventilation is effected by means of a steam jet and of an electrically-driven fan. This is of the Rateau type, and making 350 revolutions per minute, yields with a water pressure of 1·3 inch, 14,127 cubic feet of air per minute.

**American Collieries.**—J. A. Ede * gives a detailed description of the workings and surface plant of the Spring Valley Collieries, Illinois.

H. O. Prytherch † publishes an article on mining and ventilating anthracite mines with increasing depths, in which he makes suggestions as to improved methods.

## IX.—*COAL-WASHING.*

**Coal Screening and Washing.**—Illustrations have appeared ‡ of Bray's design of roller screens for coal. The coal is passed over a number of serrated discs eccentrically mounted on shafts at suitable distances, so that the material is caused to travel forward as the shafts revolve.

Illustrations are given § of G. Taylor's device for attachment to side or end tipplers. It consists of a hinged plate held by a catch, liberated at the proper moment to drop the coal gently.

Illustrations have been published ‖ of the automatic coal-dust weighing-machine as used on the screens at the Itzenplitz colliery, near Saarbrücken.

---

* *Transactions of the American Institute of Mining Engineers*, February 1899.

† *Mines and Minerals*, vol. xix. pp. 513–514.

‡ *Engineering and Mining Journal*, vol. lxviii. p. 69.

§ *Colliery Guardian*, vol. lxxviii. p. 218.

‖ *Iron and Coal Trades Review*, vol. lix. p. 346.

Illustrations of the Sheppard coal-washing plant at Rhymney, including a longitudinal section and a transverse section, have been published.* Coal is brought in ten-ton waggons, which are tipped by a special hydraulic apparatus into hoppers, whence it is taken by conveyors to elevators and then to screens. In part steam-coal and in part bituminous coal is treated, being delivered simultaneously on to the conveyors, so as to obtain perfect mixing in further treatment. Particulars of the Sheppard felspar washers are given. The capacity of this washing plant is 550 tons per day. The following figures give the results of a full week's work :—

Total quantity of coal washed, 3272 tons 3 cwts., of which
47·4 per cent. was fine coal, 0 to $\frac{5}{16}$ inch.
25·9 ,, ,, pea coal, $\frac{1}{16}$ to $\frac{3}{4}$ inch.
10·5 ,, ,, nut coal, $\frac{3}{4}$ and above.
16·2 ,, ,, shale.
100·0

Illustrations have appeared † showing the general arrangement of the Stein coal-washing plant at the new Glasgow Coal Company, Nova Scotia, and also sections of the forms of jigs used for fine and coarse coal.

Jičínksý ‡ states that the coal-washing plant belonging to Messrs. Gutmann near Dombrau, in Moravian-Ostrau, is on the Baum system, and is arranged to yield 7·5 metric tons per hour. Fine coal, under 0·8 inch in size, which is intended for the coke-oven plant, is conveyed from the jigs by a centrifugal pump to three large iron tanks, each holding 600 tons, and allowed to dry in them. It is then transferred to a disintegrator, and subsequently conveyed to the coke-ovens. The coal of larger size is kept separate.

The new screening plant at the Witkowitz Colliery (Dombrau) § is described by A. Fillunger.

An American form of jig for coal-washing is illustrated. ||

**Utilisation of Fine Coal.**—Much care and attention has been devoted at the Saarbrücken Collieries for many years past to improve their marketable products by washing and careful dressing.¶ The

---

* *Iron and Coal Trades Review*, vol. lviii. pp. 1088–1090.

† *Ibid.*, vol. lix. pp. 668–669.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii., *Beilage*, p. 56.

§ *Ibid.*, vol. xlvii. pp. 487–489.

|| *Iron and Coal Trades Review*, vol. lix. p. 394.

¶ *Neues Saarbrückener Gewerbeblatt;* through *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 127–129.

coal of this field is, however, very difficult to treat by washing, as the finer sizes can only be washed clean with difficulty. It was therefore found necessary at some mines to dry these sizes; but this led from one difficulty to another, the quantities of coal-dust produced leading financially to considerable loss. Just as the fine dried coal was a loss and a nuisance, so too was the fine coal washed away in the wet method of treatment. All kinds of methods were tried to overcome these difficulties, but without success. Finally, experiments were made with "water spray" firing methods, and these are now described. By this system the dry coal-dust can be utilised direct, and also that from the wet treatment after only a very superficial drying, and without any preliminary treatment.

The dry dust contains 26 to 28 per cent. of ash, and some 7½ per cent. of water, while that from the wet method contains some 30 per cent. of ash and 19 per cent. of water. The "water spray" firing method adopted is that of Beckem and Post, who mix together air and water in a very fine state of division and pass this mixture beneath the fire-bars of a grate. Immediately above the fire-bars an extremely high temperature results, which in turn leads to a rapid and complete combustion of the coal in the upper layers of fuel. The "water dust" is obtained by converting water under pressure into a fine spray. The pressure is never less than four atmospheres. The excess of pressure under the grate prevents the dust adhering to the bars and choking the grate. The fuel being very high in ash, much cinder results, and this has to be removed more frequently than when better fuel is used. Consequently more labour is necessary at the fires than is required under ordinary circumstances. The results are given of this method of firing as applied to boilers, full details of the costs being given, and it is pointed out that this hitherto almost waste material gave relatively extremely satisfactory results. It is able to replace other cheaper sorts of coal hitherto burnt, and that too with financial advantage. In the cases mentioned the saving amounted to several hundred pounds in the course of the year.

Some articles have appeared * giving a general view of the use of powdered coal, especially for boiler-firing, both in connection with economy and smoke prevention. Various furnaces are described.

L. Kaufmann † describes the Freitag system of coal-dust firing. Very little relating to coal-dust firing has been published during the

---

* *Schweizerische Bauzeitung*, July 8, 15, 22, 29, 1899.

† *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. pp. 988–992; with four illustrations.

last year or two, and the author thinks that this reticence points to this system not being such a success as it was at first asserted to be. The objections that have been raised to coal-dust firing are of various kinds. The plant is stated to be necessarily dearer and more cumbrous; the better coal consumption has been held to be largely counterbalanced by the power required to drive the grinding-mill; that the coal-dust must be very dry is another such objection, as otherwise the mill will clog; that the dry dust leads to danger from its explosive character; and that the dust being highly hygroscopic, it is impossible to adequately protect it from moisture, while moist dust would choke the sieves and generally prove impracticable of application.

The advantages of this system of firing, on the other hand, are fully known. It is therefore chiefly practical difficulties which have led to failure in the past. The author himself in 1895 pointed out that it appeared to be without doubt that in this system of firing the combustion of the fuel is of a very perfect character, and that the question of smoke production is very largely under control. The manual labour needed is very small, all that is required being what is necessary for the control of the coal-dust being used and of the air admitted. Other advantages lie in the fact that poor coal may be employed, and that the wear and tear of the boilers is less than when solid fuel is used. One of the very greatest difficulties connected with coal-dust firing lies in the production of the dust, and the cost of doing this is considerable. In view of these various difficulties, the author observes it is of interest to consider a modified system of coal-dust firing which is free from many of these defects. This is the Freitag system. It has been employed in the case of one boiler constantly for over two years, and in the case of five boilers in day and night use without any interruption for one year. The grinding-mills are directly attached to the boiler, and only grind at a time the small quantity of coal that is required for use, the air current used in the combustion of the dust removing this from the mills. Only in this way is it possible to obtain a clean method of firing free from dust. If coal-dust has to be moved about, trouble from dust must be always present. In the Freitag system this is entirely absent, as also are the concurrent dangers. In the author's opinion a coal containing much ash-producing constituents is not suitable for coal-dust firing, as these have to be ground up with the coal, and the ash formed tends to choke the flues, which consequently require frequent cleaning. Hitherto it has not been possible, owing to the necessity for having grinding-mills, to adapt this system of firing to ships, but this is quite possible with the Freitag method. The author describes this in detail, giving illustrations of various portions of the apparatus. One of the chief difficulties experienced with coal-dust firing has lain in the proper grinding of the coal. Here again Freitag has introduced improvements, and his grinding arrangements are quite different from those heretofore employed. In practice, as he shows, the arrangements adopted have worked perfectly, and repairs have not been necessary in one case where it has been constantly in use for over two years, nor in six others where it has been in constant day-and-night use for over a year.

Harry N. Gardner * has published an article on the accumulation of culm in the coal regions and its utilisation for power purposes, in which he shows that progress in furnaces and grates has made it possible to burn much of this culm with profit.

**Handling Coal.**—G. Little † gives a number of brief sketches of several arrangements for automatically handling coal and coke at different works with the aid of creepers and conveyors.

An illustrated account is given by A. W. Evans ‡ of the surface plant for handling coal on an incline at a colliery in Hamilton, Tennessee. The train of tubs runs down an incline attached to a main rope, and its speed is controlled by a fan geared by a friction clutch to the drum. The empties are hauled back by power. The leading dimensions and costs are given.

At a colliery in West Virginia, § the coal is allowed to run down an inclined V-shaped trough, 500 feet long, being checked by a conveyor chain of the Jeffrey type; 100 to 140 tons are thus lowered, and the system has replaced an inclined plane.

W. Fawcett || gives a short account of the machinery at the Lake Erie ports for handling ore and coal, and also appends a few illustrations.

George Johnson ¶ publishes an article on coal shipping, in which he gives information relating to business methods, charges, &c., in England.

---

* *American Electrician*, April 1899.

† *Transactions of the Institution of Mining Engineers*, vol. xvii. pp. 117-120.

‡ *Mines and Minerals*, vol. xix. pp. 534-535.

§ *Engineering and Mining Journal*, vol. lxviii. p. 339.

|| *American Manufacturer*, vol. lxv. pp. 67-71.

¶ *Colliery Guardian*, vol. lxxviii. pp. 107-108.

**Peat Briquettes.**—The utilisation of the peat moors of Northern Germany is now receiving considerable attention, the peat being turned into briquettes.* A large plant for this purpose exists at Langeanburg in Pomerania. The cut peat is first cut up small by one machine, and then ground fine in a mill. It is afterwards dried in a rotating cylinder heated by waste steam. This cylinder is slightly inclined, so that the wet pulp being charged in at one end, a stream of dried peat is constantly escaping from the other end. It is then transferred to a press which yields 80 briquettes per minute, or 35 tons a day. There is a great demand for these briquettes, which burn very slowly and give out a good heat. In a closed stove they will keep alight for at least twenty-four hours, and though they burn faster than this in an open grate, they still burn more slowly than does the best coal.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 419.

# PRODUCTION OF PIG IRON.

## *CONTENTS.*

| | PAGE | | PAGE |
|---|---|---|---|
| I. Blast-Furnace Practice . . . | 398 | III. Blast-Furnace Slag . . . | 410 |
| II. Chemical Composition of Pig Iron | 409 | IV. Foundry Practice . . . | 411 |

## I.—*BLAST-FURNACE PRACTICE.*

**Slips and Explosions in the Blast-Furnace.**—Several accounts of slips and explosions in different blast-furnaces have been contributed by J. M. Hartman, E. S. Cook, F. E. Bachman, and others to the discussion on the account given by F. B. Richards.* These occurrences seem to depend on many factors, but, to a considerable extent, their main cause seems to be ascribed to the collection of finely crushed fuel choking the air passages through the charge, and then igniting suddenly when air comes in contact with it freely, as happens when the mass falls. The nature of the ore mixtures also has an effect, especially when the gangue causes them to become pasty at low temperatures, or when they are finely divided or of different degrees of reducibility. However well the furnace is working, it is always liable to sudden changes that occur without any warning. Multiple tuyeres have been advocated as a better means of furnace control, but, in the opinion of E. S. Cook, do not seem to have any great effect. In this discussion several highly adventurous occurrences are related.

**Damping Down Blast-Furnaces.**—An account is given of the method adopted at the Le Creusot blast-furnaces to damp these down during a strike. On Tuesday, May 30th, orders were given to this effect in view of the fear of an approaching strike.† Three of the blast-furnaces were making white Bessemer iron showing but little graphite, while the fourth was making best quality No. 4. The slag in each furnace was limey in character. Immediately on receipt of the warning a diminution was made in the quantity of slag charged in the case of each of the three furnaces making Bessemer iron, and in the case of the other furnace the ore charge was lessened. The quantity of limestone charged was diminished in each case. This was done about three in the afternoon. At six o'clock fresh charging was stopped altogether in the case of two of the furnaces, and about a ton of sand was also got in readiness at each furnace. At half-past seven the strikers stopped the blowing-engines, and one of the furnaces had to be tapped without blast, but the others had been tapped previously. The tap-holes were filled in as far as possible into the furnaces with sand and then plugged up with clay. Then the tuyere pipes were disconnected, and the tuyeres and slag-hole plugged with slag, and clay was used generally to make the furnaces air-tight wherever necessary. All cooling was also stopped, the Parry cones closed, and the gas leads connected with the stack by means of the boilers. In this condition the furnaces remained until the end of the strike. On the morning of June 3rd, blast was turned on in that furnace which was at the end of the gas lead. The pressure was at first very slight, and was gradually increased from 1·81 inch to 3·15 inches. The gas lead still contained hot dust, and for this reason two charges of very strongly wetted coke were charged before the gases were allowed to pass into the leads. The ordinary precautionary measures were adopted and no explosions resulted. One after the other the remaining furnaces were similarly dealt with, two coke charges being made without other additions in the case of each furnace. After this, light charges were made for a time, especially as the coke available was of poorer quality owing to the coke-ovens having cooled down during the strike. In the afternoon from 10 to 11 tons were tapped without difficulty from each furnace, and by night-time the quality of the metal being made was again such that some of it was sent to the Bessemer works. On the evening of the following day the furnaces were working just as usual. Incidentally it is mentioned that during the Franco-Prussian war the workpeople employed at a furnace on the German border, leaving hurriedly on account of the approaching enemy, built in their hurry a wall around the crucible portion of the furnace, and then stamped clay into the space between it and the blast-furnace. Three months after this it was found that the metal in the furnace was still fluid.

---

* *Transactions of the American Institute of Mining Engineers*, vol. xxviii. pp. 902-908. Compare *Journal of the Iron and Steel Institute*, 1899, No. I. p. 369.

† *Echo des Mines et de la Métallurgie*, 1899, pp. 5486-5487; *Stahl und Eisen*, vol. xix. pp. 723-724.

**Blast-Furnace Filling Apparatus.**—Illustrations have appeared [*] of the furnace top designed by W. Kennedy for the Duluth Furnace Company. The large bell and hopper is covered by a conical gas sealing hood made in segments and provided with explosion doors. Surmounting it is a second smaller bell, above which is an oblong hopper, into which the charge is filled by two skips, which run on an inclined lift and counterbalance each other. The small bell prevents loss of gas and distributes the stock evenly over the large bell.

The Bertrand form of cup-and-cone is described.[†] In this the cone is fixed, and it is the cup which is raised instead of the reverse, as in the older type.

**Hot Blast.**—An arrangement for equalising the temperature of the hot blast supplied to blast-furnaces is being introduced by L. Gjers and J. H. Harrison. Practically, it consists in interpolating an additional stove between the ordinary stoves and the furnace and passing all the heated air through it. By this means the blast, which at first is overheated, gives up some of its store of heat, which is given up again later on when the stoves have run down. The equaliser is arranged with suitable connections for the purpose, but otherwise it is nearly after the Cowper type, with a central partition and the two sides filled with chequer-work.[‡]

**Blowing-Engines.**—A pair of blowing-engines, for the Deutscher Kaiser Company, near Bruckhausen, have been built at Muhlhausen. The engines are of the vertical compound type, in which each steam-cylinder has a blowing-cylinder immediately above it. The following are the principal dimensions:—

| | |
|---|---|
| Diameter of high-pressure cylinder | 48 inches. |
| Diameter of low-pressure cylinder | 75 „ |
| Diameters of the two blowing-cylinders | 80 „ |
| Stroke (of both pistons) | 60 „ |
| Number of revolutions per minute | 25 to 50 |

A number of sectional views are given.[§]

F. W. Gordon[‖] describes various forms of positively worked valves for air compressors and blowing-engines. The inlet and outlet valves are connected by levers and links, so as to balance each other and to work together.

---

[*] *Iron Age*, June 29, 1899, pp. 8-9.

[†] *Echo des Mines et de la Métallurgie*, 1899, p. 5528.

[‡] *Engineer*, vol. lxxxviii. p. 201.

[§] *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. p. 406; with 19 illustrations.

[‖] Paper read before the American Society of Mechanical Engineers, May 1899.

A. Riedler[*] discusses machine construction in connection with metallurgical necessities, and in particular devotes attention to the question of blowing-engines. The time is coming, he points out incidentally, when the waste gases from blast-furnaces will play a very much more important part than they now do for power production. The author considers the construction of blowing-engines in detail.

**Slag Ladles.**—The self-clearing ladles for molten slag from blast-furnaces, now in use at the Cleveland and South Bank Ironworks, differ from those hitherto in use by having a solid inner lining of cast-iron, which avoids skulls and enables the ladle to clear itself whether the slag is molten or whether through any delay it has become solid. Illustrations are given.[†]

**The Use of Blast-Furnace Gas.**—Mortier[‡] summarises some of the applications of blast-furnace gas for motive power. Steam-engines, he points out, require at the least 7500 calories to do the same work that can be performed by 3000 calories in the gas-engine. The calorific power of blast-furnace gas is shown by Aimé Witz to vary between 900 and 1100, and the same author shows that it can be utilised with advantage for gas-engine purposes. The results obtained in practice at Seraing have shown, too, that with gas having a calorific power of 880, the quantity of gas required per hour per effective horse-power is certainly less than 123 cubic feet. To obtain this result only 15 or 17 lbs. pressure is required. The various plants that have been erected are referred to, and calculations are given showing the heat from blast-furnace gases per ton of pig iron made.

Jacoupy[§] summarises the results of recent attempts to utilise the gases from blast-furnaces for the production of motive power.

F. W. Lürmann[||] refers to a previous paper[¶] of his on the subject of the utilisation of blast-furnace gases. Dealing with the objection that dust would seriously disarrange the working of the gas-engine by getting into the cylinders, he points out that he has already shown that this dust could be readily got rid of. The matter would be different if gaseous elements or compounds passed as such with the blast-furnace gases into the cylinder of the gas-engine, as when burnt there the resulting oxides or other compounds would very seriously increase the difficulties connected with the use of blast-furnace gases in gas-engines. The dust itself cannot attack the gas-engine, but containing alkalies, alkaline earths, or metallic oxides, it might thicken and change the composition of the lubricating oil present in the cylinders of the gas-engine. It is stated, however, both by those who make gas-engines and by the works that use them, that this thickening of the oil is no longer a matter of any particular importance. At the commencement of December 1898 the author saw at work at Seraing the 180 horse-power gas-engine driven by blast-furnace gas. This, he was assured, used only gas taken direct from the ordinary gas leads. Since his last paper on this subject great progress has been made in Germany in connection with this use of blast-furnace gas. One engine of 600 horse-power is in use at Hörde, two of 200 horse-power and two of 300 horse-power at the Friedenshütte, near Morgenroth; and others exist at works which the author names.

---

[*] *Stahl und Eisen*, vol. xix. pp. 761–767; five illustrations.

[†] *Iron and Coal Trades Review*, vol. lix. p. 246.

[‡] *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 54–57.

[§] *Revue Industrielle*, 1899, pp. 279–280, 289–290.

[||] *Stahl und Eisen*, vol. xix. pp. 473–489; with illustrations.

[¶] *Journal of the Iron and Steel Institute*, vol. liv. p. 459.

The author next considers the questions as to what power can be obtained from the waste gases, and what amount of money is saved by so doing. These questions he deals with in considerable detail, and shows that the saving would amount theoretically to about six shillings per ton of pig iron made. The value of this form of utilisation of the waste blast-furnace gases is, the author shows, being rapidly grasped by German iron-smelters, and he gives a list of twenty-five new gas-engines in progress of construction for German works that are to be driven by these gases. The engines mentioned vary in horse-power from 40 to 1000. The possible utilisation of blast-furnace gas as the motive agent has very greatly affected the construction of gas-engines. Thus up to a year ago such engines of 200 horse-power were thought very large, while now gas-engines of from 1200 to 1500 horse-power can be obtained. These large gas-engines could, of course, be also worked with producer-gas. This, in turn, may affect the construction of gas-producers, leading to further improvements in them.

F. Zeyringer* observes that the quantity and character of blast-furnace gases depend upon the quantity and the nature of the fuel used, the quantity of gas made being directly proportional, or almost so, to the weight of fuel used per ton of pig iron made. It follows, therefore, that large furnaces, in which, as compared with smaller ones, a saving of fuel is effected, relatively less gas is produced. A not unimportant influence on the value of the gas produced is exerted by the addition of limestone that is made, as this is nearly always charged into the furnace in its raw state, and consequently gives up its carbon dioxide in the furnace itself. This is in part reduced by the fuel in the furnace to carbon monoxide, but nevertheless it always results in greatly diminishing the calorific value of the escaping gases. If, too, the ores smelted are charged in in their raw state, they give up moisture, and frequently carbon dioxide when in the furnace, consequently also tending to reduce the calorific effect of the waste furnace gases. No doubt, also, the kind of pig iron that is made results in variations in the composition of the gas, and of its quantity, and, finally, the composition of the waste gases, especially as regards their contents of hydrogen, marsh-gas, and moisture, must be very closely connected with the composition of the fuel. The author deals in detail with the question in connection with a charcoal blast-furnace plant. This comprises three small blast-furnaces smelting brown hæmatite and spathic carbonate with from 5 to 20 per cent. of silicon. A grey Bessemer pig iron is made, and for every 100 tons of pig iron made 98·44 tons of charcoal is used. This contains 85 tons of carbon. The limestone used amounts to 25 tons, containing 38·12 per cent. of carbon dioxide. Analyses of the furnace gases showed by weight:—

---

* *Stahl und Eisen*, vol. xix. pp. 664–668.

| $CO_2$. | CO. | O. | $CH_4$. | H. |
|---|---|---|---|---|
| 18·00 | 19·00 | 0·20 | 1·60 | 0·40 |

This corresponds to 14·34 per cent. of carbon in the gas. There was charged into the blast-furnace 85 tons of carbon in the form of charcoal and 2·6 tons in the form of carbon dioxide in the limestone.

Of this total of 87·6 tons there was used in the blast-furnace—(1) in carburising the iron to pig iron, 3 tons; (2) as loss in the form of dust from the furnace, 0·6 ton; and (3) in the furnace gas, 84 tons. Consequently, for each 100 tons of pig iron made, 588 tons of furnace gases, or nearly six times the quantity, was also made. This corresponds to 4590 cubic meters of gas for each metric ton of pig iron. One kilogramme of this waste gas yields, on complete combustion, 873 heat units, or 1093 heat units for one cubic metre of the gas. The gas at the works in question is used for steam-raising purposes, and for the calcination of ore. The pig iron from the blast-furnaces is delivered direct as tapped to a Bessemer plant, and it is found that no fuel is required in the works except that used in the blast-furnaces, the waste gases from which suffice for all other purposes.

In considering various questions connected with the production and utilisation of the blast-furnace gases, the author deals with the loss of gas when the furnace is charged. The furnaces are connected together, one main gas lead serving for all three, and it is found that the loss of gas due to charging, and to the gas leads not being altogether tight, is about 10 per cent. of all the gas made. The author next gives figures relating to the quantities of gas used in the calciners, hot-blast stoves, and boilers, observing that with the best form of hot-blast stoves the heat utilised is to be placed at at least 65 per cent. He also shows how gas may be saved in various ways, and draws attention to the blast-furnace as an important source of power as well as a pig iron producer.

The heat-balance in power production with blast-furnace gases is calculated by V. Thering.*

E. Meyer † considers the question of the utilisation of blast-furnace gases in gas motors, and gives the results of experiments with it in a 60 h.-p. engine. The author points out that the best steam-engines do not convert into indicated h.-p. more than 16 per cent. of the heat available from the coal, and frequently not more than 10 or 12 per cent. Good gas-engines, on the other hand, yield 25 to 32 per cent. Gas-engines are, therefore, much more economical in this way than steam-engines. On the other hand, the fuel they use is much dearer, even when mixed producer-gas is employed. If blast-furnace gas could be used as the fuel with success, the position would be very different. For every ton of pig iron made per day, there is produced enough waste gas to run a 20 h.-p. engine. The author considers this point theoretically, and gives a series of analyses of waste furnace gas, of which the following is from a blast-furnace at Esch-on-the Alzette. Percentage by volume:—

| $CO_2$ | O. | CO. | H. | $CH_4$. | N. |
|---|---|---|---|---|---|
| 11·15 | 0·45 | 25·60 | 0·33 | 1·50 | 60·97 |

In May 1894 Thwaite took out a British patent for the use of blast-furnace gas in this way, and about the same time its use was suggested in Belgium. The author refers to the difficulties that were anticipated, and shows to what extent these have proved groundless. He then describes and illustrates a 60 h.-p. engine at the Differdingen Works, in Luxemburg, with which he has experimented with blast-furnace gas as fuel. He then describes the experiments themselves, and showing that the results obtained were most satisfactory, points out that there is an important future for the use of blast-furnace gas as a source of power in suitable gas-engines, the construction of which, of suitable dimensions, need no longer be looked upon as a matter of difficulty. The engine run by this gas at Differdingen worked in the steadiest possible manner, and during the three days during which the author had it under observation no difficulties of any kind arose, the engine running faultlessly.

---

* *Journal für Gasbeleuchtung*, 1899, pp. 225–227.

† *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. pp. 448–455 and 483–487; 12 illustrations. *Stahl und Eisen*, vol. xix. pp. 517–527.

J. Körting * considers the utilisation of waste blast-furnace gases as a source of power. A similar source, he observes, lies in the gases escaping from coke-ovens. Other waste gases that are useful as fuel are also referred to.

The utilisation of blast-furnace gas for power is dealt with † in a recent series of articles which consist largely of a translation of papers read recently in Germany and elsewhere. Plans of the Oberhausen and Seraing plants are reproduced.

**Utilisation of Blast-Furnace Dust.**—Colomb Pradel has communicated to the French Society of Agriculture a paper on the agricultural utilisation of blast-furnace dust.‡ At Pont-à-Mousson this waste product is obtained in great abundance, and is considered to be valueless. It, however, contains 4·6 per cent. of potash and 20·5 per cent. of calcium carbonate. Experiments with this dust as a fertiliser have given very satisfactory results.

**Casting Machinery.**—Illustrations are given § of W. Hawdon's pig-casting machine, in which the chain of overlapping moulds is prevented from sagging by rollers mounted in bearings, which are placed well outside, so that they may be lubricated, and are not affected by heat to any extent. The pigs are discharged at the end of the chain on to an inclined shoot, which deposits them on an annular rotating platform working in water in a tank. Thence they are removed by a fixed deflecting plate, which pushes them over the edge on to a grid, through which the arms of an endless chain conveyor passes so as to catch them and lift them to a suitable height for discharge into the railway trucks.

---

* *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. p. 554.

† *Iron Age*, July 6, 1899, p. 6; August 3, p. 3, &c.

‡ *Bulletin de la Société Nationale d'Agriculture*, April 1899.

§ *Engineer*, vol. lxxxviii. p. 111.

This machine is a modification of the plant used by the designer for handling blast-furnace slag.

Illustrations are given of Heyl and Patterson's pig iron casting plant for the Palmer Shipbuilding and Iron Company. Its capacity is given as 1500 tons in 24 hours, and it requires 14 horse-power to drive it.*

E. S. Cook † compares blast-furnace with cupola practice, and refers to the growing increase of the use of casting machines, and the advantages of sand-free pig iron. The method of casting pig iron from ladles which act as mixers is dealt with at some length, and the composition of iron is also discussed.

M. A. Moran ‡ also deals with the advantage of sand-free pig iron.

**Blast-Furnace Stack Struck by Lightning.**—An illustration is published § of the blast-furnace plant of the Friedrich-Wilhelm works at Mülheim-on-the-Ruhr. Here there is a large iron stack. This was struck by lightning and perforated in twenty-three places, the holes made, as the illustration shows, being of large size. Notwithstanding these, a diminution in the pull of the stack was hardly noticeable, and it was found possible to repair it without interruption of work.

**Charcoal Iron Furnace in Canada.**—The charcoal iron furnace at Deseronto, Ontario, has now been running five months, making about 1000 tons monthly. The stack is 61 feet in height, and the bosh diameter is 9½ feet. Blast is heated in iron pipe stoves. ||

**The Deutscher Kaiser Ironworks.**—A description is published,¶ accompanied by numerous illustrations, of the Deutscher Kaiser Ironworks at Bruckhausen-on-the-Rhine. This new work forms one of the most important and recent improvements in the Rhenish-Westphalian blast-furnace industry. The works possess coalfields of considerable area, containing caking, long-flame, and other coals. The coal is wound in five shafts, and the collieries are directly connected with the blast-furnace plant. At present 3300 tons of coal are wound in the working day, but in a few years this quantity will be nearly doubled. In 1890 the first steps were taken towards the erection of the plant, a

---

* *Iron and Coal Trades Review*, vol. lviii. pp. 952–953.

† *Journal of the American Foundrymen's Association*, vol. vi. pp. 295–313.

‡ *Ibid.*, pp. 314–317.

§ *Stahl und Eisen*, vol. xix. p. 581.

|| *Iron Age*, June 29, 1899, p. 18.

¶ *Stahl und Eisen*, vol. xix. pp. 566–572; 14 illustrations.

large open-hearth plant and rolling-mills being then laid down. This possesses at the present time seven basic open-hearths, and has a monthly capacity of 11,000 tons of ingot metal. When in 1895 the question of obtaining suitable coke was settled by the completion of a large winding shaft in the immediate neighbourhood of the works, a commencement was made with the erection of a blast-furnace plant, and also of a basic Bessemer plant. The original plant contemplated the erection of six blast-furnaces, but so far only three are in operation, and a fourth in process of construction. The further increase in the blast-furnace plant will be made to correspond with the increase in the production of caking coal from the colliery. The washed caking coal from the winding shaft near the works is conveyed by a wire ropeway to the coke-ovens. At present 188 of these are in work, and 68 in process of erection. These coke-ovens are arranged for the collection of the by-products, and when all the 256 coke-ovens are at work the monthly production will amount to 30,000 tons of coke, 1200 tons of tar, 400 tons of ammonium sulphate, and 300 tons of benzol. The coke-ovens are connected by wire ropeways with the blast-furnaces, each pair of blast-furnaces having a separate coke hoist and separate groups of coke-ovens. The ore is mostly brought by ship to the immediate vicinity of the works. Each blast-furnace produces 250 to 300 tons of basic pig iron per day. The furnaces are 82 feet high, 19 feet 8 inches wide at the boshes, and 12 feet 6 inches wide in the crucibles. To each furnace there are five Cowper stoves, 23 feet wide and 98 feet 5 inches high, and two pairs of vertical compound blowing-engines, with air cylinders 6 feet 7 inches in diameter, and a stroke of 4 feet 11 inches. Further details are given as to the blowing-engines.

The basic Bessemer plant has four 15-ton converters and two powerful blowing-engines. The present output amounts to 20,000 tons a month, which will, however, be considerably increased as the output of the blast-furnaces is raised. The rolling-mill attached is capable of a monthly outturn of 30,000 tons. Electric power is largely used at the works. There is a grinding plant for basic slag in the neighbourhood of the central electric power station. The position of the works on the Rhine is an excellent one.

**The Kraft Ironworks, near Stettin.**—According to H. Prenger,* the Kraft Ironworks at Kratzwieck, near Stettin, has been placed in what at first sight looks like the most unfavourable position for an ironworks as regards the character of the ground on which it is built, solely with a view to ensure the maximum degree of facility for cheap water transport and general railway connections. The works adjoin the river Oder. On its banks are placed four Hunt conveyors, each capable of raising 1000 tons of ore and coal from ships in the river. Thence they are transferred direct to the furnaces. The ores smelted are chiefly Swedish magnetites, Spanish calcined carbonate ores, and brown and red hæmatites, containing at least 50 per cent. of iron. There are two blast-furnaces. These are somewhat barrel-like in internal shape. The temperature in them is 100° to 150° C. at the upper part of the throat, lower down it reaches 900° to 1000° C., while in front of the tuyeres there is a temperature of about 1600° C. There are two batteries of coke-ovens, each containing forty-five, arranged for the collection of the by-products. The blast-furnace gas is used in the usual way for the stoves and boilers, first passing through large settling chambers. The slag is partly granulated. Each furnace produces from 110 to 120 tons of pig iron per day. In making the foundations for the works 14,000 piles were used.

---

* *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. p. 664.

**The Evolution of the Blast-Furnace.**—A paper of great historical and technical interest on the metallurgical industry of the region of St. Etienne is published by L. Babu.* He divides his subject into five periods:—(1) prior to 1815; (2) 1815 to 1840; (3) 1840 to 1860; (4) 1860 to 1880; and (5) 1880 to the present time.

In the Kunst-Historisches Museum at Vienna † is a picture by L. van Valkenborgh of the first half of the sixteenth century. This shows a river valley between mountains, with a small island in the stream. On this island an active blast-furnace is shown, worked by a pair of bellows actuated by a waterwheel. The bellows are attached by cords to a bent tree, serving as a spring. The furnace is rectangular in shape, and has a flight of eight steps leading part-way up one side. Up these steps a man is climbing, carrying on his shoulder a flat trough-like basket, evidently containing material to be charged into the furnace, which would appear to be about 9 feet in height. At the side of the furnace, with the steps between, is a trough, some 10 feet by 5 by 2 in dimensions, filled with molten material which is being stirred by two men with bars, and a portion of the contents is shown as flowing out at the opposite end to that at which the men are standing into a similar trough placed at a slightly lower level, and from this again into a third, apparently for the purpose of separating entangled metal from the slag. Sheds are also shown, and heaps of ore, a portion of which is being discharged from a boat immediately by the waterwheel, while two men are passing across to the island from the mainland on a primitive bridge, carrying on their backs conical baskets evidently heavily laden. Flames are shown escaping from the furnace mouth. On the opposite side of the river a village and a castle are shown, while on that adjoining the furnace, a curious commentary on the difficulties connected with transport in those days is shown by a merchant being pursued down the hillside by a man with a drawn sword and by another with a musket.

---

* *Annales des Mines*, vol. xv. p. 357.

† Communicated by E. J. Ball.

## II.—*CHEMICAL COMPOSITION OF PIG IRON.*

**Silicon and Carbon in Cast Iron.**—The notes published by B. S. Summers on modern cupola practice, with special reference to the discussion of the physics of cast iron, have led to many contributions to this subject. To a very considerable extent they turn on the relation between silicon and carbon and the iron. F. E. Bachman,* in a separate paper on the silicon control of carbon in cast iron, gives a series of 138 analyses of foundry grades of iron made at the Buffalo furnace, with some analyses of other grades in 51 tables. The averages are arranged in two tables, according to grades and according to silicon contents. It is considered that sulphur and silicon are the only elements affecting the carbon contents, but if silicon has any influence on the carbon contents of either castings or pig iron, it is too small to be of any practical value above a silicon percentage of 1·50 to 1·75. Below that percentage the lower proportions of fuel and temperature may very probably have more effect on the proportion of graphitic carbon than the silicon itself. An inspection of the tables seems to show a close relation between the sulphur contents and carbon relations.

Thomas D. West † offers further comments upon the deceptive fracture of pig iron, and gives the results of various experiments to show how the appearance depends upon the treatment, and not solely upon the composition.

---

* *Transactions of the American Institute of Mining Engineers*, vol. xxviii. p. 769.

† *Journal of the American Foundrymen's Association*, vol. vi. pp. 265–278.

## III.—*BLAST-FURNACE SLAG.*

**Utilisation of Slag.**—The Committee on Dangerous Trades, in their final report, refer to the manufacture of slag wool. Danger occurs during packing on account of the fine particles, and it is recommended that veils and respirators be worn, and that sufficient time should elapse for the air to cool and particles to settle in the collecting chamber before it is entered.

A. D. Elbers * deals with the manufacture of sulphur-free slag wool from blast-furnace slag, and points out the objections to the material containing sulphur. The wool has been made direct from the slag, but it has been found preferable to re-melt old or new slag in a cupola, with the addition of lime and sandstone, so as to make a slag slightly more acid than mono-silicate. More acid slag makes a coarser wool. So called rock-wool is made without the slag by melting lime and siliceous rock together. In practice the sulphur in both these products is reduced to 0·3 per cent., and less. It has been found that by the addition of gypsum or calcium sulphate the sulphur may be further reduced, owing to the reaction between sulphate and sulphide, and this process has accordingly been adopted to some extent in the United States. By the addition of 9 per cent. of gypsum to the charge, slag wool with 0·02 per cent. of sulphur † was produced. A cupola 42 inches in diameter inside the lining is used, with two rows of tuyeres, one 6 to 8 inches above the other, and a blast pressure of 2 to 4 ounces per square inch. From 750 to 900 lbs. are melted hourly, and the slag runs in a continuous stream, which should not exceed $\frac{3}{4}$ to 1 inch in diameter. The steam pressure used for the blast is 80 to 90 lbs. per square inch.

A. D. Elbers ‡ discusses the desulphurisation of blast-furnace slag in the molten state for the purpose of making building stone. Various proposals have been made, including the addition of sodium nitrate, and of blowing air or steam through the molten slag to oxidise the sulphur. Another idea is to add sodium silicate, which is intended to carry the sulphides to the surface of the ladle, so that they can be skimmed off.

---

* *Engineering and Mining Journal*, vol. lxviii. pp. 248–249.

† Apparently as sulphide, the sulphates not being mentioned.

‡ *Engineering and Mining Journal*, vol. lxvii. p. 708.

**Effect of Lime and Magnesia on Sulphur in the Blast-Furnace.**—O. R. Foster [*] quotes a number of authorities to show the divergent opinions and practice that obtain in regard to the relative desulphurising effect of lime and magnesia in the blast-furnace, and he gives the results of a number of crucible experiments made by melting iron containing sulphur with slags containing varying amounts of lime, magnesia, and sulphur. The results are few and inconclusive, but they show that, as a rule, more basic slags reduce the sulphur, that high lime has more effect than high magnesia, and that both have a better result than a mixture of the two bases in certain proportions.

## IV.—*FOUNDRY PRACTICE.*

**Modern Foundry Practice.**—A. Ledebur considers [†] the state of the foundry practice existing at the close of the nineteenth century. Towards the end of the previous century, he observes, the use of the steam-engine was introduced into the workshop, and water-power ceased to be an all-important factor. In the year 1825, with the opening of the Stockton and Darlington Railway, a practical commencement was made of the use of the steam-engine for transport purposes over long distances, and this in turn led to increased trade; and the author briefly passes in review the various causes and their effects which have led up to modern foundry practice, dealing in greater detail with the progress made in the second half of the nineteenth century. Beginning with a consideration of the pig iron made and the methods of testing it, the author points out that although in the sixties it was well known that white pig iron was not suitable for castings, and that this was due to the absence of graphite, yet the real cause of the formation of grey pig iron was not understood. It was long before the part played by silicon was fully recognised. Up to then this element had been looked upon as deleterious, and it is only within the past twenty years that its real importance has been fully recognised. What percentage of silicon is the best for castings depends chiefly on the dimensions they are to have. The larger they are, the more slowly will they cool down, and the lower, therefore, may be their percentage of silicon. In very thick castings a percentage of 0·5 of silicon, or even less, may be adequate to cause the metal to possess the properties of grey pig iron, while a percentage of 1·5 may be given in the case of castings of average thickness, and 2 per cent., or even more, is desirable for thin castings. As a rule, about one-tenth of the silicon present in a pig iron is lost when the metal is re-melted. The presence of manganese in a foundry pig iron was in former years often considered to be most desirable. It was thought to increase the strength of the metal. Within narrow limits this may indeed be shown to be the case, but the disadvantageous effects of a large percentage of manganese are more pronounced. It tends to make the iron white, and increases the contraction of the metal on cooling, with all its attendant evils. Even, therefore, for castings which are to be chilled, a high percentage of manganese in the metal is not permissible. Fortunately the action of the manganese is not so pronounced as to cause 1 per cent. of that element, or even somewhat more, to be dangerous in ordinary cast iron. The manganese should be kept low in thin castings, and in water pipes required to resist high pressure, and frequently subjected to sudden shocks, the percentage of manganese ought never to exceed 1. One advantage of the presence of manganese is that it tends to prevent the oxidation of the silicon when the iron is re-melted, the manganese itself undergoing oxidation. A pig iron rich in manganese can consequently be more often re-melted than one which is not, without becoming white. Still even pig iron destined for use in this way should not contain more than 1·5 per cent. of manganese.

---

[*] *Transactions of the American Institute of Mining Engineers*, September 1899.

[†] *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. pp. 433–448; with numerous illustrations.

The deleterious influence exerted by phosphorus on cast iron was known at an early date. It undoubtedly produces brittleness in the castings. This influence is increased by the presence of manganese, and diminished by that of silicon. Water pipes ought never to contain more than 1 per cent. of phosphorus, but for an ordinary casting which is not required to withstand shocks, a pig iron may be used with as much as 1·4 per cent. of phosphorus, provided the percentage of manganese is low and that of silicon adequately high. If the casting is to be used for construction purposes, it ought not to contain more than 0·5 per cent. of phosphorus.

The influence exerted by sulphur is less than that of phosphorus, as in foundry iron it rarely exceeds 0·1 per cent. Only when the metal is re-melted in cupolas with coke high in sulphur, or when no care is taken to add enough limestone to keep the slag basic, can the percentage of sulphur rise high enough to be objectionable, when it may make itself felt, especially in thin castings. The iron shows a tendency to become white and thick-fluid. When charging the first coke, if no limestone is added, the first iron that runs through will generally show these characteristics, owing to the metal being compelled to drop through the sulphurous coke without being protected by any layer of slag that could absorb the sulphur. The author draws attention to the favourable conditions existing in the United Kingdom for the production of foundry pig iron. In Germany the conditions are less favourable. Ordinary Rhenish-Westphalian foundry pig iron contains, as a rule, from 2·5 to 3·5 per cent. of silicon, 0·7 to 1·0 per cent. of manganese, and 0·5 to 1·0 per cent. of phosphorus. The so-called "hæmatite" pig iron, intended for strong castings, contains at the most only 0·1 per cent. of phosphorus. The Luxemburg and Lorraine foundry iron contains more phosphorus than the better kinds of British metal, but, on the other hand, this is partly counterbalanced by the fact that the percentage of manganese is low—0·5 to 0·6.

Dealing next with testing methods, the author in the first place refers to the results of chemical analysis. Tests should be made, he observes, for other than the more ordinary constituents. In particular, chromium may be mentioned. Very small quantities of this make the iron more brittle, even 0·1 per cent. having this effect. Next mechanical tests are dealt with. Tensile and compression tests are usually of less importance for pig iron, the author observes, than bending tests, and percussion tests should be much more frequent than is now the rule. Passing from these, the author proceeds to consider in detail foundry practice proper. He first considers the furnaces and blowing machines employed. Dealing with cupolas, several forms are enumerated and described. Next the author considers moulding and the materials and appliances in use for this purpose. Subsequently he deals with the methods in use for cleaning and surfacing the casting, various forms of the sand blast being specially referred to. The author next proceeds to a consideration of the buildings and of their internal arrangements, plans and elevations being given. The author considers generally matters relating to foundry practice, and the whole forms a most valuable monograph.

Walter J. May * has published an article on melting iron for foundry purposes, in which he discusses cupola furnaces and their management.

---

* *Practical Engineer*, vol. xx. p. 86.

Jewett* advocates the employment of two rows of tuyeres in cupolas, and gives useful hints on charging and working cupolas.

E. Herz† has published an article on the improvements in melting furnaces, in which he illustrates and describes an improved foundry cupola, with auxiliary tuyeres and heated blast, by which a high economy is attained.

At a foundry at Wilmerding, Pennsylvania, the ladles are carried by trollies running on a single overhead suspended rail, of which illustrations are given.‡

**New American Foundries.**—W. J. Keep § describes with numerous illustrations the methods for handling materials at the works of the Michigan Stove Company, Detroit, and gives a plan of the works. All heavy materials are carried on tram lines with a 20½-inch gauge, and curves as sharp as to have a 12-foot radius are employed to avoid the use of turn-tables. A travelling crane commands the yard, and lifts material to a weigh-house on the roof, whence an incline takes them to the cupola. Electricity is used as a motive power.

C. J. Wolff ‖ describes a foundry in which the cupolas and moulds are arranged on the upper floor, and the two lower floors of the building are used for other work. Light castings are made to the amount of 70 to 80 tons daily. The moulding space is 540 by 125 feet.

A. Schotte ¶ discusses the structure of foundry buildings and advocates a combination of concrete on a steel frame.

A plan of a recently erected foundry at the Schenectady works of the General Electric Company has been published,** together with a description of the electric cranes and other appliances, and also of the doors provided with ball bearings, and the racks moved by compressed air for the core-ovens. This foundry is heated by hot air distributed through the building by fans, of which an account is given.††

A. W. Walker ‡‡ describes the wash- and bath-rooms built by a

---

* *American Machinist*, 1899, pp. 384–385.

† *Oesterreichische Monatschrift für den Oeffent. Baudienst*, August 1899.

‡ *Iron Trade Review*, vol. xxxii., September 21, 1899, pp. 12–13.

§ *Journal of the American Foundrymen's Association*, vol. vi. pp. 181–205.

‖ *Ibid.*, pp. 255–258.

¶ *Ibid.*, pp. 318–323.

** *Iron Age*, April 6, 1899, pp. 1–4; *Iron and Coal Trades Review*, vol. lxiii. pp. 1037–1038.

†† *Iron Age*, April 27, 1899, pp. 10–11.

‡‡ Paper read before the American Foundrymen's Institution; *Engineering News*, vol. xlii. p. 50.

Boston company in Boston for their workmen. They are of exceptional extent and comfort.

S. H. Stupakoff* in a presidential address deals with the methods of keeping foundry records.

**The Warping of Castings.**—Moore † gives a number of examples of the warping of castings caused by unequal cooling, and describes the methods he adopts to remedy it.

**A Large Casting.**—Illustrations have appeared ‡ of some large castings forming portions of gun platforms. Each of these castings weighs 15 tons, being 14 feet in diameter and 2 feet in thickness. The hollow interior is made with dry sand cores, and the mould was held together by girders above and below, bolted together at their ends. Metal was poured from two ladles simultaneously, about five tons being run through the mould over the weight of the casting. The tensile test was specified to be between 28,000 and 39,000 lbs., and the elongation not less than 0·25 per cent.

**Malleable Castings.**—E. C. Wheeler states § that an air furnace melting 18 heats on one bottom during about a week does excellent work, but probably some modification of the open-hearth furnace fired with producer-gas and lined with dolomite will be used in the manufacture of malleable castings. Such a lining would aid in the removal of sulphur and phosphorus, and might last four months. In it coke iron could more safely be used. No improvements have been made in the furnaces of recent years, though the quality of the iron used has undergone marked changes. The metal has to be kept in the furnace until the carbon is all combined, and there is much danger of burning out the silicon, which element keeps the metal hot and fluid. The effect of manganese, carbon, sulphur, and other elements in their relation to coke and to charcoal iron is also dealt with at some length.

G. C. Davis ‖ gives another account of the history of malleable cast iron in the United States.

---

* Pittsburg Foundrymen's Association; *Iron Trade Review*, vol. xxxii., July 6, 1899, p. 11.

† *American Machinist*, 1899, pp. 618–649, 733–734.

‡ *Engineering News*, vol. xlii. p. 76.

§ *Iron Age*, April 6, 1899, pp. 5–6.

‖ *Journal of the Franklin Institute*, vol. cxlviii. p. 134–144. See *Journal of the Iron and Steel Institute*, 1899, No. I. p. 390.

In some notes on malleable castings, the use of the cupola, of the reverberatory furnace, and of the open-hearth furnace is dealt with.*

**Pattern Making.**—J. M. Richardson † discusses the importance of fillets and round corners of modern machinery castings, and gives a number of hints as to their production in the patterns used in the foundry. Leather glued in place is recommended for small fillets.

**Moulding.**—A. C. Mott ‡ gives some notes on moulding machines, briefly indicating the various types, and discusses their application to stove-foundry work, for which, in his opinion, they are not suitable.

An illustration of the Cramp pneumatic rammers at work on a large mould has appeared. The rammer head is reciprocated by a piston working in a cylinder with a 4-inch stroke and 3½ inches in diameter, and an air pressure of 35 lbs. per square inch. This cylinder is supported by a second pneumatic cylinder by which its height can be adjusted.§

For the purpose of blackening the moulds, use is made of a sprayer to distribute the liquid. ||

**Cast Iron Pipes.**—T. H. Wiggin ¶ discusses various coatings for cast iron pipes, and describes the method of coating them with crude gas-tar to which sometimes dead oil of tar is added. The pipes are passed through a furnace which heats them approximately to 300° F., and are then plunged into the bath, taken out and drained. The volatile constituents evaporate, leaving a fairly hard, smooth, and resistant coating, but the whole process is generally carried out in a very lax manner. The use of linseed oil in the bath appears to have been discontinued. Many substitutes have been suggested and used to replace the tar, and of these a brief account is given together with some rough tests. Rusty pipes soon lose the coating.

T. H. Wiggin ** describes in detail the manufacture and inspection of cast iron pipes.

---

* *Iron Trade Review*, vol. xxxii., September 28, 1899, pp. 11-13.

† *Journal of the American Foundrymen's Association*, vol. vi. pp. 236-243.

‡ Paper read before the National Association of Stove Manufacturers, through the *Iron Age*, vol. lxiii., June 1, 1899, p. 20.

§ *Iron Trade Review*, vol. xxxii., September 28, 1899, p. 16.

|| *Iron and Coal Trades Review*, vol. lviii. p. 866.

¶ *Journal of the Association of Engineering Societies*, May 1899; *Progressive Age*, vol. xvii. pp. 371-374.

** *Journal of the Association of Engineering Societies*, 1899, pp. 209-261.

# PRODUCTION OF MALLEABLE IRON.

**Manganese in the Finery Process.**—According to C. A. Jacobson,* even a small percentage of manganese in the pig iron dealt with leads to a considerable loss in fining the metal, and its presence is otherwise objectionable. Despite the fact that the pig iron is white, it is quite thin-fluid at the beginning of the fining process, and even then yields large quantities of fluid red slag. This continues until the beginning of the boil, when it lightens in colour and becomes more thick-fluid. Highly oxidising conditions result; the loss of metal is considerable, and this cannot be avoided even with the greatest care. Even 0·2 per cent. of manganese is sufficient to give bad results. The charges used in fining hearths have greatly increased in recent years, and now amount to some 330 lbs. In the thirties the charge was only about one-third of this. It is possible, however, that somewhat smaller charges than those now customary would give better results, besides being less trying to the workmen employed. In a hearth with two tuyeres the best results are stated to be obtained with charges of about 275 lbs.

**History of Iron.**—Gaillard T. Lapsley † gives a description of the account roll of a fifteenth-century ironmaster in Weardale. An idea of the wages paid may be gathered from the following:—Colier, blomesmith, and faber were paid by the piece at the following rates: A dozen horse-loads (*duodenæ*) of charcoal burnt in the bishop's park, 2s.; a "blome" (15 stone) of iron smelted from the ore, 6d.; working over a blome at the forge, 6d., and cutting it into pieces, 1d. The foreman, when he helped in these processes, was also paid at a fixed rate—*i.e.* 2d. per blome for smelting (*prima factura*), and 3d. for working the iron over (*fabricatio et purificatio*). We have, it is true, no direct mention of labourers under the foreman, but there is a note of the expenses of William Aycle, who had ridden to Wakefield and Rotherham "*pro operariis, videlicet blomers et coliers, pro dicto forgeo perquirendo.*" The wages paid to the two women, even when due allowance has been made for the heterogeneous nature of their services, the fluctuating demand for them, and the number of festivals and consequently idle days in any given week, appear to have been determined by nothing short of caprice. Take, for example, the month of December. In the first week three blomes of iron were produced; there were two festivals, and John Gylle's wife, who had been helping to break up ironstone, received 7d. The next week she was not employed. The third week, however, she was busy at the bellows for five days (there was one festival); six blomes were produced, and again she received 7d. There is no account for Christmas week, and probably no work was done; but between December 30 and January 5—five working days—she was again employed at the bellows; no iron was produced, but she took a wage of 12d. It will be noticed, however, that from June 15 she is paid regularly at the rate of ½d. per blome, but most of this time she was engaged in helping her husband.

---

* *Wermländska Bergsmannaföreningens Annaler*, 1899, pp. 67-69.

† *English Historical Review; Colliery Guardian*, vol. lxxviii. p. 176.

In a sketch of the character and career of Prince Rupert, Eva Scott * points out that his inventions were many, and were connected chiefly with the improvement of weapons and materials of war. He invented an improved lock for firearms, a kind of revolver, a method of making hail shot, and the alloy of copper and zinc called "Prince's metal" to this day. In 1671 he took out a patent "for converting edge-tools forged in soft iron after forged and for converting iron wire, and softening all cast or melted iron, so that it can be wrought and filed like forged iron" (Domestic State Papers, April 22, 1671).

An article on the successive improvements in the manufacture of bar iron has been published by Samuel Peters.†

**Composition of Swedish Iron.**—O. Thallner ‡ gives the following analyses of Swedish iron made in hearths :—

---

* "Rupert, Prince Palatine," by Eva Scott, late Scholar of Somerville College, Oxford. Westminster: Archibald Constable & Co., 1899, p. 337.

† *Proceedings of Engineers' Society of Western Pennsylvania*, vol. xv. p. 222.

‡ *Stahl und Eisen*, vol. xix. p. 914.

| No. | C. | Mn. | Si. | P. | S. | Cu. | As. |
|---|---|---|---|---|---|---|---|
| 1 | 0·33 | 0·14 | 0·080 | 0·005 | trace | 0·008 | ... |
| 2 | ... | ... | ... | 0·010 | ... | ... | ... |
| 3 | ... | ... | ... | 0·006 | ... | ... | ... |
| 4 | ... | ... | ... | 0·027 | ... | ... | ... |
| 5 | ... | ... | ... | 0·022 | ... | ... | ... |
| 6 | ... | ... | ... | 0·011 | ... | ... | ... |
| 7 | ... | ... | ... | 0·031 | ... | ... | ... |
| 8 | 0·04 | 0·07 | 0·012 | 0·012 | 0·003 | 0·017 | ... |
| 9 | ... | ... | ... | 0·021 | 0·004 | 0·011 | ... |
| 10 | ... | ... | ... | 0·022 | ... | 0·065 | 0·044 |
| 11 | ... | ... | ... | 0·061 | ... | ... | ... |
| 12 | 0·06 | 0·08 | 0·020 | 0·011 | 0·004 | 0·023 | ... |
| 13 | ... | ... | ... | 0·018 | ... | ... | ... |
| 14 | 0·041 | 0·08 | 0·017 | 0·030 | 0·008 | 0·021 | ... |

Nos. 1 to 7 are described as Walloon iron; 8 to 11 as Lancashire iron; 12 and 13 as Franche-Comté iron; and No. 14 as Swedish nail-iron scrap.

# FORGE AND MILL MACHINERY.

**Large Forging Presses.**—A description * accompanied by illustrations is given of two 10,000-ton forging presses manufactured by the firm of Breuer, Schumacher & Co., and intended for erection, one at the Dillingen blast-furnaces on the Saar, and the other at the Obuchovski Steelworks at St. Petersburg.

**Compressed-Air Tools.**—Haedicke † describes and illustrates various forms of tools for use with compressed air.

**Large Forgings.**—Some large forgings made at the Bofors-Gullspang Works, Sweden, are described and illustrated by Bennett H. Brough.‡ They comprise the ram weighing 9·2 tons for the Swedish armour-clad *Thule*, and the propeller axle, weighing 9 tons, made for the Russian Emperor's yacht *Standard.*

**Rod-Rolling.**—N. K. Turnbull § gives an interesting series of notes on rod-rolling and its development, together with particulars of some of the latest forms of mills and their productions.

Little alteration or improvement was made in rod-rolling until 1860, up to which time the practice was to reduce the billets in sectional area in a separate mill to 1¼ inch or 2 inches square, when they were reheated and passed to and fro through one stand of rolls with the necessary grooves cut in them. The output varied from 3 tons in 1830 to about 5 tons in 1860, and the weight of pieces from 10 lbs. to 25 lbs. at these respective dates, the material used being puddled iron. Then came the demand for long lengths of telegraph wire, and this resulted in the success of the Bedson continuous mill. By 1867 the product of the mill had gone up to 11 tons per day, and the weight of pieces had increased from 25 lbs. to 100 lbs.; the waste had been reduced from 10½ per cent. to $6\frac{9}{10}$ per cent., and the consumption of coal from practically 15 cwts. to 8 cwts.; to-day, one of the original Bedson mills turns out 40 tons per turn with a loss of 2¾ per cent., and rolls 340-lb. pieces in single lengths. From the year 1870 forwards it is difficult to give a correct chronological account of the development of rod-rolling. Two systems began to compete in America for pre-eminence, viz., the continuous of Bedson, developed by Daniells & Morgan, and the looping or Belgian system, brought to its present perfection by our countryman W. Garrett. To cope with increasing outputs, reeling or coiling appliances, including those of Morgan & Daniells, Edenbarn, and Cromwell-Garrett, have been brought to great perfection. They are of two kinds, pouring and receiving reels, and enable the continuous mill to be run very much faster, so that to-day some finishing rolls are running 1200 revolutions per minute, and producing rods as fine as No. 9 gauge, equal to 0·144 inch in diameter.

---

* *Stahl und Eisen*, vol. xix. pp. 606–607 ; two illustrations.

† *Ibid.*, vol. xix. pp. 610–614 ; ten illustrations.

‡ *Commerce*, vol. xiii. p. 987.

§ *Journal of the West of Scotland Iron and Steel Institute*, vol. vi. pp. 151–173.

The continuous mill with alternately horizontal and vertical rolls can only deal with one rod at a time, but by using twisted guides all the rolls can be placed horizontally, so as to deal with parallel lines of rods, and the underground gearing can be dispensed with.

In 1882 the first Garrett mill was put down for rolling 4-inch billets, and at once made 72 tons daily. Then the M'Cillip repeater for turning the squares was introduced, and has led to five or six rods being rolled at once. Repeaters have been objected to on the oval side on account of increased scrap, but they are used in this country. The sloping floor is another improvement, to take care of the loops; the improved means for charging the heating furnaces, and the German upwardly cast ingots, are other matters referred to by the author.

Attention is then turned to various mills, and short descriptions are given of the Schoenberger Company's mill, Boecker's mill with two trains of parallel rolls, the Morgan continuous mill at Joliet, and the Bedson mill at Middlesbrough.

The mill and plant designed by the author for Messrs. Richard Johnson & Nephew of Manchester is a combination of the continuous and Garrett mills, and is in some respects unique. The billets used are 26 feet long, 2 inches square, and are rolled without cutting into No. 6 rods. The roughing mill consists of 11 stands of rolls, alternately horizontal and vertical. The vertical roll housings are new, in that the drive is from the top downwards through a pair of pinions and ordinary spindles and boxes, and not upwards, as has always been the case previously with vertical rolls.

The finishing train consists of nine stands of rolls arranged for looping, but every pass speeded up so as to keep the loops as nearly stationary as possible. When fully loaded, it requires a 1250 horse-power engine to drive the mill. The heating furnace is 27 feet long by 12 feet broad, and has 33 alternate air and gas ports on each side, with regenerators underneath. Producer-gas is used for firing. The mill makes 75 to 80 tons per day of ten hours, and the scrap and furnace waste is under 4 per cent. Ten men and lads are required to work the mill. The author then compares continuous and loop mills, and advocates ball bearings for the roll necks.

**Rolling-Mill Fly-Wheels.**—J. Fritz[*] describes the construction of cast iron and steel fly-wheels for use in rolling-mills, and gives details as to their manufacture and service.

**Rolling Rails.**—The record in steel rail-making is claimed by the South Mills of the Illinois Steel Company of South Chicago, which recently rolled 1310 tons in a twelve-hours' run.[†]

**Slabbing-Mill.**—Illustrations and a plan have been published[‡] of the slabbing-mill built in 1898 at the South Chicago Works for making billets, blooms, and slabs. There are six vertical regenerating pit-heating furnaces, 6½ by 16 feet, commanded by electric cranes. The mill has horizontal rolls 84 by 32 inches with a lift of 36 inches, and vertical 20-inch rolls driven by a separate engine. The roller tables extend 40 feet on each side. The shear is 107 feet from the mill, and cuts widths up to 50 inches, and has a stroke of 28 inches. Beyond is a smaller billet shear.

**New Rolling-Mill Engines.**—A description is given by Wolters[§] of a new rolling-mill engine without a fly-wheel. This drives a 25·6-inch three-high rolling-mill at the works of the Aix-la-Chapelle Company.

C. Kiesselbach[||] deals fully with the various types of engines employed in driving rolling-mill trains. Various details of construction are dealt with in detail and numerous illustrations accompany the text.

---

[*] Paper read before the American Society of Mechanical Engineers; *Cassier's Magazine*, vol. xvi. pp. 129–132.

[†] *Colliery Guardian*, vol. lxxvii. p. 1187.

[‡] *Iron Age*, vol. lxiii., June 29, 1899, pp. 1–4.

[§] *Stahl und Eisen*, vol. xix. pp. 463–466.

[||] *Ibid.*, vol. xix. pp. 408–430, twenty illustrations; *Iron Age*, vol. lxiii., June 8, 15, 22.

Illustrations * have also been published of some newly erected rolling mill engines of German construction.

L. Ehrhardt † observes that the origin of the reversing rolling-mill engine is the locomotive type, which, like the former, must be able to work at extremely different rates of speed and be able to deal with resistances which vary greatly. The author deals with the earlier experiments, referring in particular to those of Bauschinger in 1865. The most important improvement in locomotive construction since those days has lain in the gradual increase in steam pressure up to some fourteen atmospheres. This high tension has proved itself in particular of importance in compound engines, and it is still questionable whether the greater part of the success attributed to this form of locomotive as regards saving steam is due to the increase in steam pressure or to the introduction of compounding. In the case of reversing rolling-mill engines, high steam pressures offer the same advantage as in the case of locomotives, and the higher the steam pressure the less relatively is the quantity of steam used, and the greater variations are possible in the working of the engine. The author points out, however, that there are important points of difference between locomotive and reversing rolling-mill engines, and he deals with these latter at greater length. C. Kiesselbach ‡ and L. Ehrhardt § discuss the paper.

Illustrations have appeared || of a set of horizontal reversing rolling-mill engines, built for a works in Pennsylvania. The cylinders are each 24 inches in diameter with a 42-inch stroke. They are bolted to a girder frame and have a link motion reversing gear operated by steam. The leading dimensions are given, and the details are illustrated by a folding plate of dimensioned drawings.

**Electric Power in Rolling-Mills.**—An account has been published ¶ of the electric power and lighting plant at the Frodingham Iron and Steel Company's Works near Doncaster. The current is generated by a compound engine with 18 and 26½ inch cylinders and 34 inch

---

* *Stahl und Eisen*, vol. xix. pp. 661–664; four illustrations in text and one sheet.

† *Ibid.*, vol. xix. pp. 859–866; with plate.

‡ *Ibid.*, vol. xix. pp. 866–868.

§ *Ibid.*, vol. xix. p. 868.

|| *Engineering*, vol. lxviii. pp. 171, 176, and plate.

¶ *Engineer*, vol. lxxxviii. pp. 45–46.

stroke, running at 100 revolutions and supplied with steam from Lancashire boilers fired with blast-furnace gas. The dynamo, driven by rope gearing, is a 150 kilowatt 250 volt machine. It is run at 550 revolutions to give 600 amperes. Seven motors are at work. Of these, five are of 30 brake horse-power, three actuating the live rolls and two the skids. The live rollers are driven by worm gearing from long shafts, in one case 150 feet in length. The other two motors drive a machine for charging blooms into a heating furnace. All the motors are frequently worked far beyond their rated capacity, but are of exceptionally strong construction. Further electric machinery is to be installed at these works.

In a new girder rolling-mill at Micheville, Villerupt, electric motors have been adopted for working the live roller trains of the mills, the charging cranes for heating furnaces, saws, and finishing machines, carriers to the hot beds, and the machinery in the roll-turning and fitting shop. The mills, which are arranged with their axes in the same transverse line, include a cogging-mill with a clear length of 125 feet to the hydraulic bloom shear, and four roughing and finishing trains driven by a three-cylinder reversing-mill at one end of the line, the cogging-mill engine being similarly placed at the other end. The power produced in a central station by three 250 horse-power tandem compound condensing engines, directly coupled to the dynamos and making 85 revolutions per minute, giving a current of 450 volts tension, is distributed to the different motors in the following manner:—An electromotor of 110 horse-power drives the bloom feeding rolls and the front and rear part of the girder-mill. A second, of 150 horse-power, adjacent to the large three-cylinder mill engine, drives the feed rollers of the third and fourth pairs of the mill, and the carriers for shifting the work sideways from the roughing to the finishing pairs. The two saws are driven each by an electromotor of 80 horse-power, and their roller trains on either side by one of 60 horse-power, and the carriers to the hot beds are served by another of 75 horse-power. Besides these, the fan blowing the gas-producer takes 25 horse-power, a billet shear and delivery train 75 horse-power, and the cold-finishing machines 150 horse-power. In addition to these there are two of 60 horse-power in the roll-turning shop. The results of some tests are given.*

**Central Steam Condensing Plant.**—The question of central steam condensing plant for rolling-mills is generally considered, and descriptions are given of various forms of condensers, and water-cooling arrangements are given, together with short accounts of some of the German plants now in use.*

---

* *Iron and Coal Trades Review*, vol. lviii. p. 944.

Evaporation condensers are described by H. G. V. Oldham,† and numerous illustrations are given of the various forms in use.

---

* *Stahl und Eisen*, vol. xix. pp. 186–200 ; *Iron Age*, vol. lxiii., April 20, 1899, pp. 3–8.

† *Proceedings of the Institution of Mechanical Engineers*, 1899, pp. 185–254.

# PRODUCTION OF STEEL.

## *CONTENTS.*

PAGE
I. The Carburisation of Malleable Iron . . . . . . 426
II. The Open-Hearth Process . . . . . . . . . 434
III. The Bessemer Process . . . . . . . . . . 438

## I.—*THE CARBURISATION OF MALLEABLE IRON.*

**Crucible Steel.**—R. A. Hadfield,[*] on his installation as Master Cutler, dealt with the history of the Company and of the steel trade in Sheffield. In the early days Sheffield's products were almost entirely made from imported Swedish, German, and other foreign steel. The material used was no doubt originally bought in its cemented condition, but afterwards the cementation was done here. It was, therefore, rather due to natural advantages, such as the abundance of wood, and later, the discovery of coal, that our manufacturing operations took root. As regards the materials used in the manufacture of cutting instruments of all kinds, it is clear that long before the time of Huntsman, who effected the first important advance in the manufacture of cast steel, the city drew these entirely from outside, or at any rate, those from which high quality goods were produced. This is confirmed by the statement that in 1750, or 150 years ago, no less than 4000 tons of Swedish iron were worked up here. Supplies are also said to have come from Spain. Probably after this import trade first commenced, some of the material was converted into blister steel at the then port of entry, Newcastle. Gabriel Jars, in his "Voyages Metallurgiques," 1764–74, states that there were then several manufacturers of steel at Newcastle-on-Tyne, that is, the cementation of imported bars was carried on at that city.

---

[*] *Industries and Iron*, vol. xxvii. p. 191.

This process, without doubt, originated on the Continent. There are also records that even the South of England contained "steelworks," that is, cementation furnaces, for ancient records show that in 1609 one John Hawes held the site of the Abbey of Robertsbridge, Sussex, upon which were eight "steel furnaces." In 1787, or only ten years after Huntsman's death, Gale's Sheffield Directory showed, by five or six firms entered under the heading of "Steel Refiners," that the men of Sheffield had not been slow to take advantage of the improvements effected by Huntsman. It may be of interest to add that there were in that year about a dozen firms engaged in the converting or cementation process. Names of manufacturers at that time engaged in the Sheffield trades are well known even now, and their existence to-day, as of many other old firms, is a good proof that the motto of the Cutler's Company, *Pour y parvenir a bonne foi*, has faithfully represented their aims. That the city has made continued progress in this special manufacture is shown by the following figures :—In 1835 there were 56 converting furnaces and about 564 melting holes; in 1842 there were 97 converting furnaces and about 777 melting holes; in 1856 there were 105 converting furnaces and about 874 melting holes; in 1899 there are probably at least 2000 to 2500 melting holes. In 1850, or only fifty years ago, it was thought to be a great feat when Messrs. Turton, of the Sheaf Works, produced an ingot weighing 25 cwts., afterwards shown at the Great Exhibition. Although it is difficult to fix an exact figure, it is probable that 1000 tons of crucible cast steel are each week melted in Sheffield, involving the use of about 14,000 crucibles. Many of the names of men prominent in the industry are mentioned to show how the same names have persisted.

O. Thallner * observes that efforts to replace the crucible process for steel-making by the open-hearth process have not been wanting, and experiments made in the very first open-hearth ever constructed in Germany proved † that it was not possible to do this, even when the very best materials were employed. The question whether open-hearth steel which has been re-melted in crucibles can be called crucible steel must be answered in the affirmative, even from the point of view of the crucible steel-maker, since the name is not derivable from the condition in which the raw material is brought into the crucible, but from the nature of the smelting process itself. Of greater importance is the question as to what is meant by really good "crucible steel," and whether such differences exist between Bessemer, open-hearth, and crucible steels as to enable these to be with certainty distinguished from each other. With regard to the first question, every steel which has been melted in a crucible, is free from all faults of manufacture, and is in every way suitable for the purpose to which it is to be put, is good "crucible steel." With regard to the second question, no tests exist by which it is possible to distinguish with certainty crucible steels from steel made by other processes of manufacture. Chemical and physical methods only enable conjectures to be made as to the origin of the steel, but do not allow of any certain answer. The consumer who desires to purchase "crucible steel" is, therefore, obliged to definitely ask for steel of this kind, and is then obliged to trust to the honesty of the seller as to the actual kind of material that he obtains.

---

* *Stahl und Eisen*, vol. xix. pp. 868–873, and 914–920.

† *Ibid.*, vol. xv. pp. 1–12.

It is customary to speak of all ingot steel as "cast steel," whatever its origin, and to call all steel suitable for tool manufacture "tool steel," and this without the purchaser much caring if the steel is suitable for the purpose to which he wishes to put it, whether it is crucible, open-hearth, or Bessemer steel. On the other hand, in practice the view appears to be a common one, that ingot steel is always a poor quality material, and crucible steel one of high quality. Views which are far from clear are common as to what is "cast steel" and what "crucible steel;" and further, it is a matter of common belief that open-hearth steel must always be a cheaper product than crucible steel. The author shows that this may be far from being the case. The aims of the crucible steel manufacturer appear to be partly to obtain a better product by the aid of the crucible process from cheaper materials, and partly to produce a product of the highest quality. Poor quality metal is often used in the crucible steel process when only a very homogeneous dense metal is required, usually in conjunction with certain definite tensile properties, and which is not required for manufacture into tools of high quality. The author deals with this question, and then observes that the production of the highest quality metal was the original aim of the crucible steel-maker, and this is based on the use of the very best raw materials. The old form of crucible furnace with coke fires is still common in the United Kingdom, but is ceasing to be employed in Austria and Germany. In the United Kingdom clay crucibles, he observes, are used almost exclusively, but in Austria graphite crucibles are employed, containing percentages of carbon that vary according to the quality of the steel that is to be produced. The re-melting of the steel in the coke furnace takes place at a higher temperature than in the gas furnace, but is of shorter duration. The less impurity is taken up from the crucible, the less is the quantity of carbon in the crucible, and of manganese in the charge. The less the percentage of carbon in the metal melted, the less the degree of reduction of the contained oxides and of the occlusion of gases by the metal, the result being a metal more or less permeated by gas bubbles. This, he observes, is actually the case with English tool-steel poor in manganese and silicon, for which reason it is customary, he states, to submit the steel in English work to a forging process to improve its density. When crucible steel is melted in coke fires in crucibles containing no carbon, the percentages of manganese and silicon remain practically unchanged, while the percentage of silicon is reduced during the melting in the proportion in which it is used as a reducing and deoxidising agent. As an example of the best kind of English crucible steel, the author takes Huntsman steel. This, he says, has shown on analysis the following results:—

| C. | Mn. | Si. | P. | S. | Cu. |
|---|---|---|---|---|---|
| 1·31 | 0·14 | 0·05 | 0·010 | 0·003 | 0·011 |
| 1·44 | 0·14 | 0·10 | 0·015 | N.D. | N.D. |
| 0·96 | 0·13 | 0·09 | 0·012 | N.D. | N.D. |

It is difficult, the author remarks, to make crucible steel of the above composition that is free from blowholes and oxides, while its actual cost is not inconsiderably increased by the subsequent forging. To avoid this, manganese is added to the charge, with the result that a steel is obtained which is freer from blow-holes, but also on the average somewhat higher in manganese and silicon than the above. The author then gives some thirty analyses made in Germany of imported English crucible steels suitable for various purposes. These varied as regards their contents of carbon and other elements between the following limits:—

| | Maximum per Cent. | Minimum per Cent. |
|---|---|---|
| Carbon . . . . . . | 1·48 | 0·78 |
| Manganese . . . . . . | 0·58 | 0·23 |
| Silicon . . . . . . | 0·25 | 0·04 |
| Phosphorus . . . . . | 0·04 | 0·01 |
| Sulphur . . . . . . | 0·035 | 0·012 |
| Copper . . . . . . | 0·035 | 0·033 |

Some of these steels, he points out, bear striking resemblances, as regards chemical composition, to Swedish Bessemer steel. The following analyses are also given of chrome and tungsten steels from the United Kingdom, sold in Germany as Kayser Ellisson steel:—

| | 1. | 2. | 3. | 4. | 5. | 6. |
|---|---|---|---|---|---|---|
| | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Carbon . . . | 1·080 | 1·220 | 1·030 | 1·240 | 1·140 | 1·490 |
| Manganese . . | 0·460 | 0·360 | 0·460 | 0·300 | 0·360 | 0·350 |
| Silicon . . . | 0·170 | 0·130 | 0·150 | 0·130 | 0·190 | 0·170 |
| Phosphorus . . | 0·013 | 0·018 | 0·016 | 0·014 | ... | ... |
| Sulphur . . . | trace | trace | 0·011 | ... | ... | ... |
| Copper . . . | 0·018 | 0·010 | 0·010 | ... | ... | ... |
| Tungsten . . . | 0·370 | 0·360 | 0·130 | 0·300 | ... | 0·380 |
| Chromium . . | ... | ... | ... | ... | 0·340 | 0·410 |

When hard steel is melted down in a graphite crucible, more carbon can be very readily taken up from the crucible and a bad product result, more especially if much silicon is present, and graphite may readily tend to separate out; and this too all the more readily the lower the percentage of manganese as compared with that of the silicon also present. An analysis of such a spoiled crucible steel has shown:—

| | Per Cent. |
|---|---|
| Graphite . . . . . . . . . . . . | 0·69 |
| Combined carbon . . . . . . . . . | 0·75 |
| Manganese . . . . . . . . . . . | 0·21 |
| Silicon . . . . . . . . . . . . | 0·16 |
| Silica . . . . . . . . . . . . | 0·34 |
| Ferrous oxide . . . . . . . . . . | 0·095 |

If the percentage of silicon in the finished steel exceeds that of manganese, hard steel melted even in a crucible low in carbon may subsequently show the presence of graphite. This happened with a steel containing after re-melting 0·92 per cent. graphite, 0·51 per cent. combined carbon, 0·25 per cent. manganese, and 0·36 per cent. of silicon. In addition to carbon, sulphur also passes from the crucible into the metal, and this more from graphite crucibles than from clay crucibles, the graphite used in crucible manufacture containing from 0·03 to 0·20 per cent., or even more, of sulphur, and nearly the whole of the sulphur contained in the crucible passes into the steel melted in it. The result is that crucible steel nearly always shows a higher percentage of sulphur than did the raw materials. The author gives the following analysis to show how steel changes in composition when melted in a crucible containing 20 per cent. of graphite (with 75 per cent. carbon) and 0·05 per cent of sulphur :—

| | C. | Mn. | Si. | P. | S. |
|---|---|---|---|---|---|
| | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Calculated from charge | 0·986 | 0·36 | 0·09 | ... | ... |
| 35 minutes after fusion | 0·926 | 0·31 | 0·17 | 0·017 | 0·0187 |
| 65 ,, ,, | 0·897 | 0·30 | 0·19 | 0·022 | 0·0206 |
| 95 ,, ,, | 0·884 | 0·28 | 0·22 | 0·015 | 0·0212 |
| 125 ,, ,, | 0·869 | 0·31 | 0·25 | 0·017 | 0·0214 |

Swedish finery hearth iron is very rarely treated in a graphite crucible. The carbon of this metal being too low, it is subjected to the cementation process. The coarsely crystalline structure that results cannot be completely eliminated either by hardening or annealing, but only by mechanical treatment. The following table shows the relationship existing between the carbon contents and the crystalline structure. No graphite could be detected :—

| | Total Carbon. | Carbide Carbon. | Hardening Carbon. |
|---|---|---|---|
| | Per Cent. | Per Cent. | Per Cent. |
| No. I. Very coarsely crystalline | 1·48 | 0·820 | 0·660 |
| No. II. Coarsely crystalline | 1·42 | 0·820 | 0·600 |
| No. III. Fine grained with a few coarser por- | 1·51 | 0·765 | 0·745 |
| No. IV. Fine grained | 1·31 | 0·630 | 0·680 |
| No. V. Very fine grained | 1·01 | 0·470 | 0·540 |

The author further gives a large number of analyses of Styrian crucible steels used for different purposes. The maximum and minimum percentages in these are as follows :—

| Carbon. | Manganese. | Silicon. | Phosphorus. | Sulphur. |
|---|---|---|---|---|
| 1·48—0·34 | 1·15—0·24 | 0·40—0·16 | 0·061—0·010 | 0·035—0·000 |

In addition, copper is shown in a number of cases, the maximum percentage being 0·018. Three of the steels contained tungsten in quantities of respectively 2·53, 2·67, and 2·97 per cent. One steel shows 2·24 of chromium. A considerable number of analyses of other kinds of steels are also given. In connection, with one of these which contained 3·81 per cent. of tungsten, it is pointed out that in the crucible the presence of tungsten leads to a diminution in the sulphur contents of the metal. This steel contained 1·30 per cent of carbon and 0·18 of manganese, no phosphorus, 0·01 of sulphur, and 0·20 of silicon. The author draws a series of deductions, showing (1) that the impulse towards the formation of a particular structure is observable throughout all the conditions through which a steel may pass, and that (2) any particular condition brought about in the steel by heat or mechanical treatment cannot be produced lastingly without changing the structure of the metal. With these two points he deals at some length.

**An Austrian Crucible Steelworks.**—A. Harpf* describes a crucible steelworks at Schloss Schöndorf, near Vöcklabrück, in Upper Austria. It is provided with water-power in quantity adequate for the works' use. The crucibles used are purchased ready-made, and are of Passau graphite. The furnaces are cylindrical, 27 inches in diameter and 24 in depth. They have conical covers, suspended by chains from a crane. This gives a fuel space above the crucible which amounts to about 15 inches. The grate is replaced by a freely perforated cast iron plate, the blast being introduced through a central pipe underneath. The crucibles are usually used only once, and never more than twice. Seven are placed in the furnace at one time. A melt lasts three hours in all, the preliminary heating lasting about an hour, and the actual melting about one and three-quarter hour to two hours.

The charge for each crucible is about 39½ to 44 lbs. in weight, and 150 lbs. of coke is used for every 100 lbs. of finished molten metal. After three weeks the furnace is stopped for repairs. The following are some partial analyses of the raw materials used:—

| | Graphite. | Comb. C. | Si. | Mn. | P. | S. |
|---|---|---|---|---|---|---|
| | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Grey pig iron . | 3·006 | 0·551 | 2·278 | 1·831 | traces | traces |
| White pig iron . | ... | 3·600 | 0·070 | 1·475 | traces | traces |
| White charcoal iron . . . | 0·150 | 4·000 | 0·420 | 1·030 | 0·019 | 0·003 |
| Charcoal spiegeleisen . | ... | 4·250 | 0·390 | ... | 0·058 | (Cu. 0·02) |
| Cement steel . | ... | 1·330 | 0·080 | 0·050 | 0·015 | 0·005 |

A forge pig iron also used contains from 0·04 to 0·06 of phosphorus and 0·03 to 0·05 of sulphur. Spiegeleisen from Assling, in Carniola, with 12 per cent. of manganese, ferro-silicon with 10 per cent. of silicon, and, for very hard steels, a small quantity of ferro-tungsten, containing 30 per cent. of tungsten, are also employed. Ferro-chrome with 30 per cent. of chromium, and ferro-nickel with a similarly high percentage of nickel, are also in use at this works in the manufacture of chrome and nickel steels. For deoxidising purposes aluminium is employed. This is 98 per cent. pure.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 253–258; with sheet of illustrations.

The author illustrates some more modern forms of furnaces holding nine pots that have been erected at this works, and describes the course of operations in them. They are provided with pre-heating chambers, and have resulted in a considerable saving in the quantity of fuel used, this being now about equal in quantity to the weight of the finished iron made, or even less, coke being the fuel used. The further treatment of the metal is described, and also its subsequent manufacture into files, the raw material for which contains from 0·7 to 1·5 per cent. of carbon, and not more than 0·03 per cent. of phosphorus. As hardening material for the cut files is employed a mixture consisting of 42 lbs. ground calcined hoofs, 60½ lbs. salt, 2·6 lbs. rye-meal, and 0·1 lb. of potassium ferro-cyanide. This mixture is made into a paste with yeast and water, the files being then rubbed over with it, dried and heated in special hardening ovens, which the author illustrates. This coating with the hardening mixture serves two purposes. It gives the necessary extra carbon to the surface of the metal and also protects the finer teeth of the files from decarburisation and oxidation. The red-hot files are removed from the ovens and plunged rapidly into a concentrated salt solution, and the hardened files are subsequently cleaned with a sand-blast. The works described also make a specialty of the manufacture of military supplies, such as saddles, cavalry breast-plates, bullet-proof shields, &c. The cuirasses are made of metal, of which mechanical tests showed a tensile strength of 62½ tons per square inch, with an elongation of 9·5 per cent., and a reduction of area of 38·45 per cent. Such a plate, 0·3 inch in thickness, resisted excellently a Mannlicher rifle-bullet, the surface being only slightly indented, whilst a similar bullet completely penetrated a sheet of commercial open-hearth steel, 0·4 inch in thickness. All sorts of other products are also made at this works, the raw material being in all cases the crucible steel that is made at the works. This the author states is of excellent quality. It is subjected to lengthened hammering and similar treatment, and this the author considers is likely to make it more homogeneous and denser throughout than would be possible were rolling alone employed.

**The Electric Smelting of Iron and Steel.**—Trials have, according to E. Hubon,* been made at Rome with the Stassano process for electrically smelting iron ore, and it is stated that the results obtained are such that works for the annual production of 4000 tons are to be erected. In this process the ore is mixed with carbon, and submitted to the heat of an arc produced between two carbons.

A. Gérard † observes that the cast iron to be used in the electric manufacture of steel might be cast in a vessel having an orifice in the bottom. This orifice would lead to a hollow cylinder lined with fire-resisting material, and having carbon poles at the sides through which a current would pass across the cylinder as the molten pig iron fell through it. Lower down the molten metal would meet a blast of hot air for the elimination of the carbon, silicon, &c. Ingot metal would collect at the bottom of the cylinder. The cost of converting a ton of pig iron into steel in this way is estimated at only four or five shillings.

## II.—*THE OPEN-HEARTH PROCESS.*

**Improving Open-Hearth Steel.**—A. Ledebur ‡ observes that he considers it as without question that it is possible to greatly improve open-hearth metal, and to convert it into a steel closely resembling crucible steel by prolonged treatment in a crucible. The addition of ferro-manganese in the open-hearth not only tends to decompose dissolved ferrous oxide, and so reduces the formation of carbon monoxide which would be formed by the action of this ferrous oxide on the carbon contents of the metal, but also tends to prevent the evolution of hydrogen, which would be driven out by the escaping carbon monoxide just as the passing of one gas through water drives out another gas that may have been dissolved in it. This cannot be performed completely either in the converter or in the open-hearth. The manganous oxide resulting from the addition of the ferro-manganese is not in itself entirely unacted on by the carbon dissolved in the iron, or otherwise it would be impossible to reduce manganese from its oxides by carbon; but the time during which this action could take place is too short to admit of it being of any great importance, nor can the interaction between the ferro-manganese and the ferrous oxide, with the subsequent separation of the manganous oxide, be complete in so short a period as elapses between the addition of the ferro-manganese and the pouring and the solidification of the finished metal. The metal to which the ferro-manganese has been added always, therefore, contains dissolved ferrous oxide, even when an excess of the ferro-manganese has been employed, and, in addition, manganese oxide, either in solution or in suspension. In any case, the quality of the metal must be affected by these residual impurities. To leave the iron for a longer period in the open-hearth, after the addition of the ferro-manganese, would, however, be useless, as this would give facility for the formation of fresh quantities of oxide and the solution of more gases. It is a different matter when a crucible is employed. The iron is not then exposed to the gas current, and time can be given to allow of the completion of the reaction above mentioned, and of the separation of the products resulting from it. Even when no manganese is present a reduction of the ferrous oxide will take place in the crucible, the carbon of the crucible as well as that of the metal taking part in the reduction, and the carbon monoxide so formed rising through the metal will help to expel the dissolved hydrogen. The process is the same as that which takes place in the ordinary crucible methed. The author does not consider it at all possible that similar results could be obtained by heating the metal on an acid hearth with a neutral flame, as has been proposed. According to Sir Lowthian Bell, a current of gas is of an oxidising nature when for every nine parts of carbon monoxide there is even only one part of carbon dioxide. Even, therefore, if the current of gas used was free from water vapour, it would be difficult to maintain a purely neutral gas, besides which water vapour is, as a matter of fact, always present, and the ratio of carbon dioxide to carbon monoxide even in unburnt gas often greater than that above referred to.

---

* *Mémoires de la Société des Ingénieurs Civils*, vol. lii. pp. 424–431.

† *L'Industrie Electro-chimique*, vol. iii. p. 7.

‡ *Stahl und Eisen*, vol. xix. pp. 438–439.

A. Sattmann * considers the use of large proportions of soft pig iron in an open-hearth charge, no iron ore being used. Scrap, he points out, is growing scarcer, and there would be a limit to the progress of the open-hearth process if a large percentage in the charge was a matter of necessity. The desire to avoid this led to the use of iron ore in the place of scrap, or of using a pig iron that had been submitted to a preliminary treatment. The first of these is only

---

* *Stahl und Eisen*, vol. xix. pp. 956–966; fifteen illustrations.

profitable under specially favourable conditions. The capacity of a plant using the pig and ore process in place of the pig and scrap method is very greatly diminished, and the other expenses proportionately increased. Large quantities of slag are formed, and hinder the chemical and thermal action of the flame in the open-hearth. In adopting the second method, either the pig iron is first treated in a converter, or hot blast is blown on to the surface of the pig iron contained in a separate receptacle. The first method necessitates the use of a pig iron high in elements whose combustion will tend to keep the metal molten. Such a pig iron costs more than a softer pig iron with a smaller contents of these elements. It is on this difference in price that the commercial success of the joint Bessemer open-hearth process depends. Where very cheap coke is obtainable, the results may be satisfactory; but where blast-furnace coke is expensive, the prior treatment in the converter will not be adopted. There are no satisfactory data available as to the success resulting from treating the pig iron by the other method of blowing on its surface. This method appears to have advantages over the converter method, but even here the pig iron must contain a certain and adequate quantity of heat-forming constituents. These considerations lead the author to suggest a modified process. This consists in the use of a white pig iron and of a minimum quantity of scrap in a special way which the author describes. He points out that in order to utilise an oxidising flame as completely as possible, the metal must expose a maximum surface to the flame, and this is only possible if it exists in the form of separate and small masses. The author therefore refines only small quantities of metal at a time, and subsequently collects these small quantities of almost finished metal into larger masses. The pig iron is allowed, after separation from the slag, to flow away steadily from the blast-furnace, and while it is flowing from the blast-furnace to the open-hearth it is subjected to the action of oxidising flames, which partially or almost entirely eliminate the silicon, manganese, carbon, &c. How this can be done the author shows, illustrating his suggested arrangements by means of sketches. The metal flowing from the blast-furnace passes first into a slag-separating receptacle, and then into a long hearth where it is subjected to blow-pipe jets from a series of tuyeres, after passing which it flows into the open-hearth. The illustrations given comprise plans of plants arranged on this method, for which the author claims numerous advantages. These include less first cost of plant, increased production, a lower cost of production, and the use of poorer qualities of pig iron, as well as others.

A brief description of the open-hearth steel process is given by Schindler.*

**Open-Hearth Furnaces at Barrow.**—Dimensioned plans and elevations of the new fifty-ton open-hearth furnaces at Barrow Steelworks have been published.†

**Open-Hearth Plant at Hayange.**—M. Lencauchez publishes ‡ drawings of the new open-hearth plant erected at Hayange (Lorraine).

**American Open-Hearth Steelworks.**—A. Berglöf § describes the plant of the Kellogg Weldless Tube Company of Findlay, Ohio, where raw petroleum is now used in the furnaces since natural gas ceased to be obtainable in adequate quantity. The oil is sprayed by the aid of steam, and a strong flame results from its combustion. The largest of the two open-hearths is of 25 tons capacity, and is basic lined. The charge contains from 55 to 60 per cent. of pig iron, and is worked off in from five to five and a half hours, although the carbon contents of the metal before tapping is always brought down to 0·1 per cent., and occasionally to 0·07. The metal is recarburised by coke powder, which is added in the ladle in the form of paper cartridges when 6 inches of metal has been run in, the pan being so placed that the inflowing metal causes the metal in the pan to have a rotatory movement. In this recarburisation about 50 per cent. of the carbon that is added burns away. In the case of smaller charges there appears to be greater uncertainty connected with this method of recarburising, and it appears, too, not to be adapted for high carbon contents. The pig iron used at the works is mostly Alabama metal, containing:—

| Phosphorus. | Sulphur. | Silicon. |
|---|---|---|
| 1·00—0·68 | 0·080—0·038 | 1·92—0·40 |

Using 10 to 12 per cent. of lime, the phosphorus is brought down to from 0·020 to 0·006 without tapping off the slag, and with recarburisation. On account of its cheapness a pig iron was purchased originally intended for the basic Bessemer process, and containing :—

---

* *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. p. 460.

† *Iron and Coal Trades Review*, vol. lix. p. 574.

‡ *Mémoires de la Société des Ingenieurs Civils*, vol. liv. pp. 116–124.

§ *Jernkontorets Annaler*, vol. liv. pp. 116-124.

| Phosphorus. | Sulphur. | Silicon. |
|---|---|---|
| 2·21 | 0·625 | 0·56 |

and a product was obtained from this which contained 0·025 per cent. of phosphorus, about 0·5 to 1 cwt. of lime being always added shortly before the metal was tapped. The author observes that although a pig iron high in sulphur is used and scrap containing 0·03 per cent., the finished metal rarely contains more than 0·025 per cent. of sulphur, and usually only 0·02 per cent., while it is occasionally as low as 0·010. This may be due to the character of the firing, which enables the metal to be rapidly melted down, and to the slag being kept very fluid by the aid of fluor spar, or of a by-product which is stated to consist of calcium fluoride and sand. The author describes the manufacture of pipes at this works, and then refers to the various methods in use at different works for putting in the basic linings into open-hearths. The more magnesia the material contains the better will it prove in practice.

A short account has appeared* of the steelworks of Jones & Laughlins, Limited, at Pittsburgh. There are two 9-ton converters and six 40-ton open-hearth furnaces. The number of the mills and their sizes are given.

## III.—*THE BESSEMER PROCESS.*

**The Barrow Steelworks.**—A ground plan of the Barrow Hæmatite Steelworks as they are at the present day has recently been published, together with an account, mainly historical, of the works, and also the following illustrations :—

Plan of the Barrow Steelworks and mills in 1879. Plan of the same works in 1891. General bird's-eye view of the works at the present time. View of the blast-furnace plant, showing inclined planes and pig iron casting beds. General view of the Bessemer converters from the platform. Ingot-stripping plants. Ingot-mould carriages. Rail-rolling plant, showing finishing mill, with roughing rolls in the rear. Front side of the rail cogging-mill plant. View showing the operation of shearing a plate. Overhead crane conveying the plate to the shears. Back side of the light plate-mill.

---

* *Iron Age*, May 25, 1899, p. 7.

The plant consists of fourteen blast-furnaces, with blast heated to 1270° F. by Cowper and Whitwell stoves. Six inclines are used instead of hoists, and the present capacity of the furnaces is 720 tons each. The Bessemer plant now includes four 18-ton converters, a marked contrast to the eighteen 5-ton converters which were erected when the process was started. A raised charging platform, 16 feet in height, is used for charging, and transfer cranes take the ladles to a central casting crane for pouring. The trolly ingot system has replaced the pit system. All iron from the furnaces is passed through a 130-ton mixer. The present open-hearth plant is equal to an output of over 120,000 tons of ingots per annum. There are four 25-ton, four 50-ton, and one 8-ton furnace for providing the metal required for castings.*

The metal mixer is placed almost half-way between the blast-furnaces and the Bessemer converters, and the metal is run from the blast-furnaces in large ladles specially constructed for the purpose. The mixer has a capacity of 120 tons, and has the following dimensions:—Top, 16 feet 5 inches inside; bottom, 14 feet 6 inches inside; height, 7 feet 6 inches at back end; height, 4 feet at front end; length, 17 feet 6 inches inside. The motion is conveyed to the mixer through a worm and a pinion on the main shaft, the worm spindle being driven by a high-pressure vertical engine, the cylinders of which are 14 inches diameter by 18 inches stroke. A short account is also given of the rail-mill and of the light and the heavy plate-mills, and other details of the works.

The Bessemer steel manufacturing plant of the Barrow Hæmatite Steel Company † has been illustrated by reproductions of the working drawings, showing the details of the new 15-ton Bessemer converters, four in number, which were built after the designs of J. M. While; a plan of the ingot-stripper; the arrangement of the levers for the strippers; the car-pusher for the new Bessemer plant; the details of the staging for the car-pusher, and incidentally of the 17-ton ladle used to convey the molten steel from the converters to the ingot moulds; the cranes; and the new type of ingot-casting car, the use of which has been attended at Barrow with much convenience and economy. The plant has now been working for over a year.

**The South Chicago Bessemer Works.**—Plans, sections, and photographic illustrations of the South Chicago Bessemer Steelworks have been published * to show the remodelled arrangements for casting. The circular pit is now displaced by ingot trucks on a straight track. There are three 14-ton converters in line, and in front of them is an elevated line of rails which has hampered the work to some extent. Two ladle cranes are mounted in front of the converters, each serving two converters, and they convey the metal to two casting cranes which can be swung to command the track on which the ingot moulds run. One of these cranes will serve both tracks, and the other only one. The metal is poured from the receiving ladles into the casting ladles and the mixing is thus promoted. The plans also show the ladle cranes, truck movers, and other appliances. All the four cranes are of 14-ton capacity. The output in May was 69,282 tons of ingots.

---

* *Iron and Coal Trades Review*, vol. lix. pp. 205–210.

† *Ibid.*, vol. lix. pp. 619–622.

**A Japanese Steelworks.**—T. Wada,† general manager of the Imperial Steelworks of Japan, supplies some particulars of the new plant now in course of construction at Yawatamura, Chikuzen, Japan.

The works occupy 215 acres. The production is expected to be 45,000 tons annually of Bessemer steel and a like amount of open-hearth steel. Rails, girders, plates, and various manufactures will be made. There is to be established a coal-washing plant, having a capacity of 1200 tons per day, and 200 Coppée coke-ovens, taking 6-ton charges and equipped with two pushers. A series of storage bins for flux and ores and a brickmaking plant are a part of the equipment. The ores are to be calcined in twenty Westman kilns 33·4 feet high, fired with furnace-gas and having a daily capacity of 40 tons. They will be served by two electric hoists. The blast-furnace plant has two 75 feet furnaces with 23 feet bosh, with a capacity of 165 tons per day, being equipped with two electric hoists. There are eight Cowper hot-blast stoves 98·4 feet high and 19·7 feet in diameter. There are four horizontal cross compound blowing-engines with 35·4 inch high-pressure, 51·2 inch low-pressure steam-cylinders, 74·8 inch blowing-tubs and 59 inch stroke, running at a speed of thirty-four revolutions, and delivering blast at a pressure of 10 lbs. A battery of twenty-four Lancashire boilers, 7·2 feet in diameter and 36 feet long, and a condensing plant are to be provided.

In the steel department is a mixer plant consisting of two mixers with a capacity of 160 tons, provided with hydraulic tilting arrangements. Three cupolas with a melting capacity of 200 tons are to be built, backed by an electric hoist and three electric blowers. The Bessemer plant proper consists of two 10-ton Bessemer converters, with a capacity of 400 tons per twenty-four hours. The Bessemer blowing-engine is a horizontal cross compound engine, with 43·3 inch high-pressure and 66·9-inch low-pressure cylinder, 59-inch blowing-cylinder and 59 inch stroke. The engine is rated at 1600 horse-power, delivering blast at a pressure of 29·2 lbs. per square inch. There are two spiegeleisen cupolas. Casting is done with the aid of three 15-ton ladles, handled by a 20-ton electric travelling crane, the ingot moulds being moved by a hydraulic car-pusher.

---

* *Iron Age*, July 6, 1899, pp. 1-4.

† *Ibid.*, July 13, 1899, pp. 13-14.

The open-hearth plant is to have four 25-ton furnaces with four air-reversing valves, and four gas-reversing valves, twelve gas-producers backed with two electric fans. A Wellman charging-machine with a maximum lifting power of 1½ ton is to be provided. The casting appliances include a 50-ton electric travelling crane and two 30-ton casting-ladles. In the stripper-house there will be a hydraulic stripper of the American type, and two hydraulic mould-pushers. Seven pit-reheating furnaces backed by producers will be served by a 3-ton electric travelling crane. In the blooming-mill there is one two-high reversing train with 43·3-inch rolls 110·2 inches wide, equipped with ingot tipper, hydraulic manipulator, and live rolls driven by electric power. The blooming-mill engine, of the horizontal type, will have steam-cylinders of 47·2-inch diameter and 51·2 inch stroke, and is rated at 4000 horse-power. For handling rolls there will be a 25-ton hand gantry crane. The ingot shear is to cut hot ingots up to 12 inches square, being of the steam-hydraulic type. The rail-mill is a two-high reversing train with three stands, the rolls being 30·7 inches in diameter and 7·22 feet long. They are served by electric power roller-tables, and have a 10-ton electric travelling crane. The rail-mill engine is of the horizontal three-cylinder type, with 43·3-inch steam-cylinder and 47·2-inch stroke, and a rated horse-power of 5800. The hot bed will be 130 feet long and 100 feet wide, while there are in the finishing department four double straightening machines and sixteen electric drills.

A two-high reversing engine of 5800 horse-power with three stands of 25·6 inch rolls backed by one heating furnace is used for bars and shapes, and there are a number of other mills for plates and shapes.

**Registering Speed of Blowing-Engines.**—A device for registering the speed of Bessemer blowing-engines or of colliery winding-engines, that had recently been adopted at the Alexander pits, was seen in operation by members taking part in the Teplitz Mining Congress. This tachograph, as it is called, is the invention of J. Karlik of Kladno, in Bohemia, and appears to have satisfactorily overcome the difficulties hitherto experienced with appliances of the kind. The chief drawbacks of the tachographs hitherto employed have been the complicated construction and their high price. Moreover, their governors have proved not equally sensitive for equal differences in velocity, and for several days' record very long or very many strips of paper are required. With Karlik's tachograph, however, the construction is simple, the price low, the sensitiveness leaves nothing to be desired, and the record for a day or for a week is shown on a single strip of paper of moderate length. Like all appliances of the kind, the Karlik tachograph consists essentially of the governor, and of the registering device. The governor is of novel design, and consists of three communicating tubes, a wide central tube and two narrow side tubes. The side tubes have a peculiar shape based on mathematical calculations. On rotating this series of tubes, filled to a certain height with mercury, the mercury sinks in the central tube and simultaneously rises in the side tubes, in such a way that the amount of the depression in the central tube is directly proportional to the number of revolutions. A float on the surface of the mercury is suitably connected with a recording device consisting of two pens filled with red and blue ink, one being movable and recording the curve, while the other is fixed and records a base line. The drum on which the paper strip is placed moves by clockwork, and is so arranged that the diagrams are written in a spiral form above one another. In this way, on a strip of paper of moderate length, a great number of consecutive diagrams may be drawn, and the whole record of the day's or week's work clearly and conveniently recorded.

**The Bertrand-Thiel Process.**—H. M. Howe* explains the greater rapidity of the Bertrand-Thiel process—1. By the greater room available for metal; (*a*) because less slag is formed, owing to washing out much of the phosphorus and silicon with a relatively acid slag, and to oxidising by means of gangueless iron oxide instead of iron ore; (*b*) because, since the first slag is removed, a smaller proportion of the total slag is present on an average of the whole time. 2. By the higher temperature, due to highly preheating the pig and iron oxides before their reciprocal reaction begins. 3. It is made possible by the greater fluidity resulting from that higher temperature of metal and slag, by the small quantity of final slag, and possibly by the larger ratio of iron oxide to lime in that slag.

---

* *Engineering and Mining Journal*, vol. lxviii. p. 276.

**Combined Bessemer and Puddling Process.**—S. Peters* suggests improvements in the manufacture of bar iron by combining the Bessemer and puddling processes. A method formerly in use consisted in melting a good brand of mill pig iron in a cupola, blowing it in an acid converter until free from silicon and most of the carbon, then transferring to a balling-furnace or a Danks rotary furnace lined with iron ore, and then treating it until the metal came to nature, after which it was squeezed or hammered into muck bar. It is now proposed that a method somewhat on those lines should be returned to, only that the furnace should be lined with bauxite or magnesite, and the metal worked in a bath of slag sufficiently basic to remove the phosphorus. Slag to the amount of a quarter the weight of the iron treated and containing about 15 per cent. of silicon could be used.

**Basic Slag.**—The manufacture of manure from basic slag is a source of danger to the workers, and the Committee on Dangerous Trades have made certain recommendations dealing with means for obviating the production and effect of the very fine dust, both in the grinding and in the packing of the material. Veils and respirators for the workers, fans and cowls for drawing off the dust, separate eating places, and dust-impermeable bags are the chief points of the suggestions.

**The Use of Carbide of Silicon.**—F. J. Tone† states that the use of carbide of silicon in the manufacture of steel was first proposed in 1893, and that during the past two years it has found wide application. The material known as carborundum shows on analysis:—

| Silicon. | Carbon. | Iron. | Aluminium. |
|---|---|---|---|
| 62 | 35 | 1·5 | 1·5 |

The effect of silicon on a bath of steel is twofold—it reduces or deoxidises the gas, and it causes the steel to be capable of absorbing gas. The material is used as a ladle addition, and it is stated that it raises the temperature of the metal and its fluidity, owing to the fact that it is an endothermic compound. Carborundum is sometimes used together with ferrosilicon, and sometimes alone. The analyses of one heat showed:—

---

* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xv. pp. 222–230.

† *Iron Age*, June 22, 1899, pp. 5–6.

| | Carbon. | Silicon. |
|---|---|---|
| In the bath . . . . | 0·09 | 0·02 |
| In the addition . . . | 0·32 | 0·55 |
| Total . . . . | 0·41 | 0·57 |
| In the bath after the addition | 0·21 | 0·25 |
| Removed as $CO_2$ and $SiO_2$ . | 0·20 | 0·32 |

It is also proposed to use carborundum as a softener for pig iron by adding it to the cupola charge in the form of briquettes.

# FURTHER TREATMENT OF IRON AND STEEL.

**Damask Steel.**—D. Tschernoff,* whose valuable collection of damaskeened sword-blades is well known, describes the best of the four methods of producing this high grade and artistic material. Twelve pounds of pure iron is placed in a crucible, and covered with a mixture of a pound of graphite, one-third of a pound of iron scales, and half a pound of dolomite. The crucible is covered and placed in a charcoal furnace. In three to three and a half hours the mass is melted, the thin layer of slag carrying upon its surface the excess of graphite. If the damask surface of the finished product is to be very hard, eight pounds of the iron is used instead of twelve. The length of the fusion affects the quality of the metal. In the time given above, about a quarter pound of graphite is lost. With four hours the loss runs up to 0·4 pound, and the metal assumes a wavy, watered appearance. Longer melting causes a loss of half a pound of graphite and reduces the effect of damaskeening; this is also the case if the crucible tilts too much. After the process is ended, the blast (of about six to eight ounces) is turned off, the crucible is allowed to cool with the furnace, and the metallic mass finally taken out of it. The lump of steel thus produced is now forged at a low temperature to the proper shape, hardened, and finished up in the usual manner. The other three methods (all four being found originally by Mr. Anossoff in his studies on the ground) are: (1) A treatment of iron ore with graphite; (2) smelting iron with charcoal, and adding iron scales to reduce the carbon partially; and (3) carburised iron subjected to a prolonged reheating in an air-tight vessel.

**Electric Welding.**—An account is given of the electric welding of tram-rail joints in Buffalo, United States.† The process has been greatly improved, and is now very satisfactory. The plant used consists of five cars; the first is a sand-blast car, which prepares the joint; this is followed in succession by the welding car, the transformer car, the motor and booster car, and a car that follows in the rear to smooth any roughness in the joint. Welding bars, 8 by 3 by 1, are placed over the joint, and a pressure of 1400 lbs. between the jaws of the welder is applied by means of a hydraulic jack applied to its upper end; the current is then turned on until the metal becomes hot enough, when the welding is finished.; the current is then interrupted and the pressure is increased 35 tons. The other welds are made in the same way. The current is taken from the regular trolley wire. These rails do not, as might be expected, buckle or break when there is a rise of temperature.

---

* *Iron Trade Review*, July 20, 1899, p. 11.

† *Electrical Review*, August 25, 1899.

**The Manufacture of Propeller Shafts.**—D. B. Morison* strongly urges the use of iron for propeller shafts, and states that in 1898 there were 173 casualties to shafts at sea, and 1000 shafts were condemned and renewed' in British-owned steamships. The four chief factors governing the life of a shaft are material, workmanship, corrosion, and wearing down of the stern-bush. Ingot steel is excellent for all purposes except propeller shafting, where it is liable to corrosion grooving, from which iron is comparatively free. Best selected scrap-iron is largely used for welded piles for the manufacture of shaftings, but it is absolutely essential that it should be free from steel, as the mass containing steel is non-homogeneous, and therefore does not weld well, and is liable to corrosion. Even if good scrap-iron is used, it is very necessary that the scrap should be of uniform size and quality, and carefully piled to obtain uniform heating. Better results are obtained with iron of special section built up into piles, such as the special lockfast iron, which consists of flat bar with two ribs on one side. Preferably these are piled so as to lie in one direction, breaking joint and not crosswise, as more uniform heating can be obtained.

**Forging Wrought Iron Axles.**—A report has recently been made to the Railway Master Blacksmiths' Association which deals with the best way of making wrought iron axles. The selection of the old material, the size and arrangement of the piles, the method of and furnaces for heating and reheating, and the method of working are described.†

---

* *Engineering*, vol. lxviii. pp. 264–267; with illustrations.

† *Iron and Coal Trades Review*, vol. lix. p. 577.

Details are given * of the large propeller shaft for the steamer *Deutschland*, now under construction at Stettin. This steamer is to be of 16,000 tons and 33,000 horse-power. The cast steel crank shaft is of considerably larger dimensions than that of the *Kaiser Wilhelm der Grosse*. Its length is 59 feet 9½ inches and its diameter 25¼ inches, with a throw of nearly 73 inches. The total weight is 101½ metric tons. The metal of which this shaft is composed showed, with test pieces 7·87 inches in length and 0·79 inch in diameter, a tensile strength of 38·09 tons per square inch, with 20 per cent. elongation. The limit of elasticity was 25·78 tons per square inch. The total weight of the shaft of the *Kaiser Wilhelm der Grosse* is only 40·3 metric tons, the metal having approximately the same ultimate strength and elongation.

**The Manufacture of Anvils.**—An illustrated account has appeared † of the manufacture of anvils by an American firm. The top and bottom halves are made separately from welded piles of wrought iron under a steam-hammer and press. A steel face is welded on to the upper half, and the horn and tail ends fashioned under a hammer, and then the two parts are welded together. The anvil is finished by hand hammering, the face hardened from a dull red heat under water-jets and ground.

**Seamless Tubes.**—Wilson ‡ describes the production of seamless tubing. He discusses the raw material of Swedish and American origin used, the Mannesmann process of rolling hollow blocks and tubes, and the modifications of the process by Stiefel.

**Cast Steel Bells.**—Three cast steel bells have recently been placed in position at the church of St. George at Berlin. They are each about 6 feet 7 inches in diameter and from 7 feet 9 inches to 9 feet in height, the weight being 17·634 tons and the cost about £920. They were made at Bochum, and are to be worked by an electro-motor. §

**Railway Waggons.**—An illustration has appeared || of one of the 50-ton iron ore bogie waggons which have been built at the

---

* *Stahl und Eisen*, vol. xix. pp. 724–725.

† *Iron Age*, May 11, 1899, pp. 1–4.

‡ *Journal of the Association of Engineering Societies*, June 1899, pp. 275–287.

§ *Der Praktische Maschinenconstructeur; Echo des Mines et de la Métallurgie*, 1899, p. 5624.

|| *Iron and Coal Trades Review*, vol. lviii. p. 1047.

Caledonian Railway Company's works at St. Rollox. The new vehicle runs on two four-wheeled bogies, has steel under-frame, three doors on each side, concave journals, and measures in length over the ends of the buffers 38 feet 4 inches.

**Steel Dam for a Reservoir.**—A dam across Johnson's Canon in Arizona, capable of containing 40,000,000 gallons, has been built of steel with a concrete wall along its toe and a short abutment of concrete at each end. The steel portion is 190 feet long at the crest, with a maximum height of 40 feet; it is composed of a row of steel frames 8 feet apart, having a slope of 45° on the water face. The covering plates, dished to increase their resistance to pressure, are steel, $\frac{3}{8}$ inch thick, about 16 feet long by 8 feet broad.*

**The New East River Suspension Bridge.**—This bridge has four cables, two on each side, and the method employed in anchoring them is mentioned in *Stahl und Eisen.*† The total weight of one of the four anchorings is about 880 tons. The bars, bolts, &c., used are all of acid open-hearth metal with less than—

| Silicon. | Phosphorus. | Sulphur. | Manganese. |
|---|---|---|---|
| 0·1 | 0·05 | 0·03 | 0·05 |

and from 0·15 to 0·25 per cent. of carbon. Material with less than 0·3 per cent. of manganese was given the preference.

**Ornamental Ironwork.**—In a paper on metal-work read before the Sheffield Society of Architects, T. Swaffield Brown ‡ discussed the principles that govern the choice of material, and the degree of elaboration to which it should be subjected. He gave some examples of bad design in ironwork, and suggestions for the avoidance of rust ravages.

The subject is also dealt with by Richard Glazier.§

C. B. Albree || gives a number of illustrations of iron ornamental work in various forms, both ancient and modern, to show its capabilities for modern decorative work and æsthetic treatment. Amongst the examples, full details are given of the panels made for bridge railings

---

* *Engineer*, vol. lxxxvi. p. 148.

† Vol. xix. p. 681.

‡ *Journal of the Royal Institute of British Architects*, vol. vi. pp. 36–43.

§ "A Manual of Historic Ornament." London: B. T. Batsford, 1899.

|| *Cassier's Magazine*, vol. xvi. pp. 577–590; *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. xv. pp. 150–172.

in New York, and the methods of producing the various parts are described.

J. Nangle * discusses the ornamental treatment of iron and steel in building work.

**Cold Process Galvanisation.**—L. Quivy † describes the various systems of Heathfield and Rawson, Cowper-Coles, Walker, and others, for the cold galvanisation by means of electro-chemical deposition. By these methods, which are much more rapid than the old hot processes, it is possible to give to cast and wrought iron a dense and uniform coating of zinc, which is strongly adherent. The arrangements of the baths, with anodes and cathodes, are shown diagrammatically, together with the modes of employing the electrical current. The preparation of the articles to be galvanised, and the composition of the salts in the baths, are given at some length.

An experimental plant is illustrated and an account is given of carrying out the entire process as undertaken by the author, with figures relating to the actual cost. The recent impetus given to this system of galvanising in France is due to its employment for steel tubes for marine boilers.

S. Cowper-Coles ‡ deals with some recent applications of electro-metallurgy to mechanical engineering, including galvanising and the removal of mill scale.

**The Manufacture of Tin Plates.**—W. C. Cronemeyer § deals with the history of the manufacture of tin plates and describes the methods now in use in South Wales. The various noteworthy improvements that have been introduced are also referred to, such as the more extended use of electric or pneumatic cranes for handling the material and changing the rolls, the different mechanical devices used for charging the annealing furnaces, separate motors for working the doubling shears, the arrangement of the cold rolling-mills, and the use of separate motors in the tinning-house for driving the different machines.

In the cold-rolling department some important improvements have been made. With the old style, all the cold mills were arranged in the same line, and the plates after being fed through the first time had to be carried round the line to be fed into the second stand, and so on. Now the cold mills are usually arranged "tandem," so that the plates passing through the first stand may be taken on straight to the next. Where a boy is employed to do this, it is common to arrange the mills "staggered," so that by turning part way round, the boy can take a bunch of plates which have come from the previous mill, and feed them into the next mill without getting up. The latest improvement is, however, to have feed-rollers between the mills, so that when the plate is fed into the first stand, it is mechanically fed through the other two. There are several devices which are desirable, in this latter case, to throw out a plate after it has passed between the first pair of rolls if its edge has been turned or it has been "pinched," because such a plate would injure the surfaces of the other rolls. One of these attachments consists of a lever, which a boy throws, and the plate then passes up and out of the line of feed, and the boy's duty is merely to watch the plates as they come out of the first stand of rolls, and throw the lever every time he sees a spoiled plate.

---

* *Report of the Seventh Meeting of the Australasian Association for the Advancement of Science*, vol. vii. pp. 994-995.

† *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, 1899, p. 380.

‡ Paper read before the British Association.

§ *Iron and Coal Trades Review*, vol. lix. pp. 347-348.

P. Pasquier * describes in detail the modern methods of tin plate making and considers the possibility of their introduction into Belgium.

**Enamelled Iron Ware.**—J. Vollkommer † describes the manufacture of enamels. But little use was made of enamel for coating iron ware fifty years ago, and now the trade is very great. The nature of enamels, and the materials and processes used in their preparation, are described. Sheet metal is annealed, and pickled to clean it. Cast iron should be free from surface graphite and is cleaned by a sand-blast or otherwise. As a rule, the articles are coated in the wet state with ground enamel made into a thick cream, and then they are dried and burnt in muffle furnaces so as to be out of contact with the fire. In some instances the enamel is dusted on to the surface. Illustrations are given of the furnace and various recipes for suitable enamels.

**Workshop at the Charlottenburg Technical High School.**—At the Technical School at Charlottenburg, a new workshop was commenced in 1896, and has since been completed. This is provided with a large number of engines of various types, and the arrangements are now described by Josse.‡

---

* *Revue Universelle des Mines*, vol. xlvi. pp. 221-242.

† *Iron Age*, August 10, 1899, p. 6; August 17, p. 9.

‡ *Stahl und Eisen*, vol. xix. p. 452.

# PHYSICAL PROPERTIES.

**The Microstructure of Iron.**—A. Sauveur* gives a general account of the mechanical uses of metallography. The polishing and etching of the specimen is described, and a number of illustrations are appended to show the structure of steel and other metals. Amongst others are some diagrams to show how, as the carbon increases, the ferrite disappears and gives place to pearlite, until at about 0·80 per cent. the entire mass is pearlite. With a further rise of carbon content the pearlite gives place to the gradually increasing cementite.

A number of photomicrographs are reproduced in the yearly volume containing the results of work at the Watertown Arsenal.† Many of them are from sections of steel rails which were tested in 1891, and the others are from rifle barrel and receiver steel, of which particulars are included in the same volume. The photographs number twenty-three, and the magnification in all cases is 83 or 85 diameters, the reproduction being excellent. One is taken from fragments of a burst gun, showing thermal cracks penetrating the tube from the surface of the bore.

The progress of metallography in 1898 is discussed by A. Sauveur.‡

**Physical Analysis of Steel.**—J. Parry§ reviews the subject of the physical analysis of steel, and summarises some of the results of Osmond, Roberts-Austen, Metcalf, and others, dealing especially with the solution theory, and the effect of quenching, and treatment generally on steel. In the author's opinion chemical analysis must be supplemented by physical analysis to secure the best results.

**The Texture of Iron.**—E. Heyn‖ observes that the various kinds of iron are comparable to crystalline rocks. The subdivision of these latter into simple and complex is equally applicable to metals and their alloys, and in particular to the different varieties of iron. To the one subdivision would belong iron very poor in carbon, while to the other would belong those varieties of iron which are rich in carbon and other constituents. The author next deals with metallography and its aims. It is still very far, he observes, from any satisfactory attainment of them, although considerable progress has been made in some directions, and the author deals with these generally, and in particular with the progress that has been made in obtaining a more perfect knowledge of the carbon-iron alloys. The author next refers to the various ways in which this knowledge has been acquired, and briefly mentions the methods that have been adopted with this end in view. He considers that the chief results have been derived by the use of the microscope, and by observing what happens when metallic alloys are allowed to cool. These two branches of the subject the author distinguishes by the names "microscopy" and "kryoscopy," with each of which he deals in detail, describing both the methods of making observations and the results that have been obtained. The various constituents of steel are enumerated and described. He gives the following table showing how these vary as the percentages of carbon increase:—

---

* *Engineering Magazine*, vol. xvii. pp. 977–992.

† *Report of the Tests of Metals*, Washington, 1899, p. 411; eleven plates.

‡ *The Mineral Industry*, New York, 1899, vol. vii. pp. 765–775.

§ *Proceedings of the South Wales Institute of Engineers*, vol. xxi. pp. 30–40.

‖ *Stahl und Eisen*, vol. xix. pp. 709–714, and 768–771; with two plates.

| | Percentage of Carbon. | | |
|---|---|---|---|
| | Under 0·8. | 0·8 to 1·0. | Above 1·0. |
| Unhardened metal. | Ferrite with quantities of pearlite increasing with the increasing percentage of carbon. | Only pearlite. | Pearlite and cementite. |
| Hardened metal. | Ferrite and martensite. | Only martensite | Martensite and cementite. |

With reference to the kryoscopic portion of metallography, metallurgists generally, and Ledebur in particular, have long held that alloys are but solidified solutions, and this applies also to those of iron and carbon. The author compares the curves of Guthrie and Roberts-Austen, dealing respectively with the solidification by slow cooling of salt and water and of iron and carbon. He deals in further detail with the question of the critical points, and with the theory of hardening of steel, and the question of segregation by liquation is also considered, as well as that of blowholes. He also indicates various points that still require further investigation.

**Magnetic Properties of Iron and Steel.**—A. M. Thiessen [*] has investigated the hysteresis of iron and steel at ordinary temperatures, and at the temperatures of solid carbon dioxide. Tool steel, steel with 5½ per cent. of nickel, and soft annealed wrought iron were examined. At high temperatures the hysteresis loss is always less than at lower temperatures.

H. S. Webb [†] also has investigated hysteresis losses for small ranges of induction.

S. S. Clark [‡] has experimented upon the normal curve of magnetisation of iron.

The effect of fibrous structure in iron, on its change of length when magnetised, has been determined by E. Rhoads. [§]

E. Dumont [||] has determined the permeability at temperatures between - 78° C. and + 250° C. of twelve samples of nickel steel in a field of from 14 C.G.S. units to 50 C.G.S. units by Ewing's method. The nickel steel was used in the form of wires of from 0·4 millimetre to 1·0 millimetre in diameter. Full details of the experiments are given, and the results are also shown graphically. An alloy containing 22 per cent. of nickel and 3 per cent. of chromium showed no trace of magnetism even at the lowest temperature. Another alloy of 35·7 per cent. nickel, containing chromium, lost its magnetism at 210°, while a similar alloy without chromium retained its magnetic properties up to 235° C. The effect of chromium seems to be manifested in this lowering of the temperature of transformation. All the reversible alloys, at an equal distance from the point of transformation, have the same magnetic permeability, and the magnetic permeability increases with the percentage of nickel.

L. Dumas [¶] has examined magnetically steels with from 0·6 to 0·8 per cent. of carbon, 0·5 per cent. of manganese, 20 to 25 per cent. of nickel, and 2 to 3 per cent. of chromium. These steels are not magnetic at ordinary temperatures, nor do they become so in the cold even after immersion in liquid air. Starting from this point as a basis for the experiments, the author has found that the point of magnetic transformation is not solely dependent on the changes in the percentage of nickel, but that it can be lowered by additions of carbon and manganese. In this way steels can be obtained which are non-magnetic at low temperatures, even when only low percentages of nickel are present. Certain steels with a percentage of nickel which exceeded 24 acquired on cooling a magnetism which was not permanent, that is to say, which did not continue at ordinary temperature. Others of similar composition became permanently magnetised by the action of cold. One sample possessed the peculiar property of being successively non-magnetic at - 15°, non-permanently magnetic at - 78° C., and permanently magnetic at - 188°. The influence [exerted by carbon is clearly a preponderating one. A few thousandths of this element suffice to bring the point of transformation to about - 188°, while that of alloys of iron and nickel, which always, moreover, contain some carbon, never descends below 0°. The percentages of manganese in the steels examined were so low that the relative influence exerted by these elements may be neglected. It had been added to prevent the separation of carbon in the form of graphite. Chromium is a still stronger "solvent" for carbon than is manganese. It exerts a very favourable action on the ductility of the metal both in the hot and in the cold, and this led the author to prepare some samples containing chromium in addition to nickel. In most of the samples so prepared the action of the carbon was still found to preponderate, but it appeared to be *nil* when the iron was almost completely replaced by nickel. On the other hand, chromium does not lower the point of transformation in the case of steels low in nickel, but it does so considerably in the case of steels in which the iron has been completely or almost entirely replaced by nickel. As in the case of the steels containing no chromium, the magnetism acquired by the action of cold is still sometimes permanent and sometimes non-permanent. Four samples with very varying percentages of nickel, and containing very considerable quantities of chromium, remained non-magnetic even in liquid air. The greatest diminution in the point of transformation was obtained by the joint action of carbon and chromium.

---

[*] *Proceedings of the American Association for the Advancement of Science*, vol. xlvii. pp. 115–117.

[†] *Ibid.*, p. 137. [‡] *Ibid.*, p. 137. [§] *Ibid.*, p. 136.

[||] *Comptes Rendus de l'Académie des Sciences*, vol. cxxvi. pp. 741–744; *Archives des Sciences Physiques et Naturelles*, Geneva, vol. v. 1898, pp. 331 and 426.

[¶] *Comptes Rendus de l'Académie des Sciences*, July 3, 1899; *Echo des Mines et de la Métallurgie*, 1899, pp. 5624–5625.

F. C. Caldwell * shows that the addition of silicon between the limits of 1·8 per cent. and 4·6 per cent. always increases the permeability of cast iron. Details of the experimental results are given in graphic form.

---

* *Electrical World*, vol. xxxii. p. 619; *Proceedings of the American Association for the Advancement of Science*, vol. xlvii. pp. 133-134.

The magnetic hysteresis of cobalt has been investigated by Professor Fleming,[*] A. W. Ashton, and H. J. Tomlinson, who conclude that, although in general form the magnetisation curve for cobalt resembles that of cast iron, its hysteresis exponent is similar to that of annealed soft iron. The absolute hysteresis values corresponding to various maximum flux densities are, however, not very different from those of a typical variety of cast iron.

E. Merritt[†] has investigated the resistance of iron wires for alternating currents. For low currents and for sufficiently high currents the resistance is practically the same for direct and for alternating currents, but at a certain strength it becomes three times as great for alternating currents. This is explained by differences in the saturation, as at a certain strength the iron has greater permeability, and the current is concentrated in the outer layers, and so throttled.

G. Claude[‡] discusses the magnetic properties of iron at low temperatures. Experiments were made with a ballistic galvanometer. The metal tested was in a cylindrical form, and in determining the temperature the author employed toluol thermometers graduated to $-150°$ C. These register the temperatures accurately to $-130°$ C. Between $-140°$ and $-150°$ the toluol solidifies with augmentation of volume. The variations observed between $+25°$ and $-185°$ having scarcely varied with the changes in temperature, only the results observed at these maximum and minimum temperatures are given. The magnetic permeability at $-185°$ C. differs by less than 2·5 per cent. from that at $+25°$. The hysteresis is also remarkably constant. There is a very slight diminution only in both cases as the temperature is lowered, and the author's experiments at temperatures down to $-185°$ correspond with those of Thiessen, the temperature in whose experiments did not go below $-80°$ C.

A paper on the electric conductivity and magnetic permeability of an extensive series of steel alloys by W. F. Barrett and W. Brown[§] gives the main results of four years' work on upwards of a hundred different alloys of steel prepared by R. A. Hadfield. For the purpose of investigation the alloys were prepared in the form of rods 106 centimetres long, and about 0·5 centimetre diameter. The electric conductivity was determined by the potential method, and referred to Matthiessen's standard of pure copper as 100. Some of the alloys could not be obtained in a homogeneous condition; those which could be, were divided into three classes: (1) those with one element added in varying proportions, of which there were eight groups containing about fifty different alloys; (2) those with two elements added, of which there were fourteen groups also with fifty different alloys; and (3) those with three or more elements added, of which there were five groups with six different alloys. The results were plotted in curves, and show the strikingly different effect which the addition of different elements has on the conductivity of iron; the alloys of tungsten and steel diminishing the conductivity least, and those of aluminium and silicon most, manganese having almost as great an effect as the two latter. In all cases the conductivity rapidly falls with small additions of a foreign element up to 2 per cent. in some cases, and 7 to 10 per cent. in others, after which larger additions of the foreign element have but a small effect on the conductivity. In the case of eight different alloys the material was obtained in the form of wire and strip, and the specific resistance and temperature coefficient determined in this condition. The highest resistance was obtained with a nickel-manganese steel alloy marked 1414 B., which gave the enormous resistance of 97·52 microhms per cubic centimetre, and the remarkably low temperature coefficient of 0·085 per centimetre per 1° C. Another similar alloy, marked 1414 A. with somewhat less nickel, had a specific resistance of 90·62 microhms per cubic centimetre and a temperature coefficient of 0·1046 per centimetre per 1° C. Another gave 89 microhms. These exceed rheostene, also an alloy of nickel and manganese steel, which was found by the authors in 1895 to have a specific resistance of 83·1 microhms per cubic centimetre, and a temperature coefficient of 0·109 per centimetre per 1° C. The second part of the paper deals with the magnetic properties of these alloys. Permeability tests were made, and complete H. and B. curves obtained for forty-four different alloys. The results are given in the curves and tables attached to the paper. A standard curve was obtained of the purest commercial iron containing less than 0·03 per cent. of carbon. In the case of the tungsten steel, the results are extremely remarkable, and of practical importance in the discovery of the best alloy for the construction of permanent magnets. The effect of nickel in the magnetic permeability is also very striking: here, as in other cases, the thermal treatment of the alloy after manufacture was a matter of much consequence. The rods were therefore all submitted to the same thermal treatment, and the permeability taken after annealing. In addition, duplicate sets of many of the alloys were made in the annealed and unannealed condition, and the electric conductivity and magnetic permeability with complete B. and H. curves determined in both conditions. The annealing process consisted of heating the rods to a temperature of 1000° C. in a large annealing furnace, and then allowing them to cool very slowly down to the temperature of the air. This took nearly 100 hours, or upwards of four days and four nights.

---

[*] Paper read before the Physical Society, June 23, 1899.

[†] *Proceedings of the American Association for the Advancement of Science*, vol. xlvii. pp. 118-119.

[‡] *Comptes Rendus de l'Académie des Sciences*, July 19, 1899.

[§] *Nature*, vol. lix. p. 502.

J. S. Stevens and H. G. Dorsey * have succeeded in demonstrating a minute increase in the modulus of elasticity of an iron rod when magnetised. The rod was supported as usual at the ends and weighted in the middle. It was surrounded by an air space, a water-jacket, and a magnetising coil outside the latter. The great difficulty consists in the elimination of heating, but this seems to have been effectually accomplished. For the motion of the interference fringes indicating the stiffening of the rod on magnetisation was instantaneous, and ceased instantly on breaking the current. Besides, on substituting a bar of copper for the iron bar, no instantaneous displacement was observed, though there was a slow creeping due to heat. To give some figures:—Length of steel rod, 66·3 centimetres; breadth, 1 centimetre; thickness, 0·54 centimetre; turns of helix, 132 per centimetre; current, 0·6 ampere; magnetising force, 99·6; displacement, 0·25 wave-length of sodium light. In the case of steel little difference was observed for loads of 1 and 0·5 kilogramme. In the case of wrought iron the smaller load gave the greater displacement when equal magnetising forces were used.

H. Le Chatelier † publishes an article of the changes of the state of iron and steel, in which he gives the results of investigations into the phenomena of recalescence and of magnetic and physical transformation.

**Theory of Deformation of Metals.**—Brillouin ‡ assumes that metals are composed of very small crystalline elements, possessed of elasticity but deprived of viscosity, enclosed in a surrounding network of viscous material not possessing elasticity, and from this standpoint discusses the laws of permanent homogeneous deformation. The deformations due to the crystalline and viscous components of the metal are calculated, and are expressed in mathematical terms. The time element comes into play in respect of the term representing the viscous flow, and is shown to be of great importance in tensile and other tests, especially when the application of the load is not uniform or continuous. Many of the irregularities in the results obtained in testing, which have usually been ascribed to defects in the metal, may probably be accounted for in this way. When the load varies rapidly without shock, the deformation is elastic, and the coefficient of elasticity is defined as being fixed by the amount of the sudden variation of the deformation when produced without shock. Thus, to obtain the coefficiency of elasticity, the initial value of the alteration of the deformation must be measured. After a stop of great length under the action of a load, a small deformation effected rapidly without shock is purely elastic. After discussing a cycle performed at a constant rate, interrupted by stops under load, the author gives some geometrical illustrations, and concludes by indicating the treatment of torsion and bending, and also the influence of temperature and physical properties of the metals.

---

* *Electrician*, vol. xliii. p. 759; *Physical Review*, August 1899.

† *Comptes Rendus de l'Académie des Sciences*, July 31, 1899.

‡ *Annales de Chimie et de Physique*, vol. xiii. 1898, pp. 377–404.

**The Effect of Temperature on the Strength of Iron and Steel.**—R. C. Carpenter* states that the effect of decreasing temperature is to increase the strength and to raise the elastic limit without sensibly affecting the modulus of elasticity or the elongation. A low temperature does not tend to increase the brittleness of wrought iron.

J. Russner † summarises the results of recent researches on the dependence of the tensile strength and elasticity, the electric conductivity, and the specific heat on the temperature.

F. Osmond ‡ has published an article on the effect of low temperatures upon certain steels, in which he discusses some experiments made upon steel cooled with liquid air, especially with regard to its magnetic properties.

---

* *Proceedings of the American Association for the Advancement of Science*, vol. xlvi. pp. 181-182.

† *Dingler's Polytechnisches Journal*, 1899, pp. 141-143.

‡ *Comptes Rendus de l'Académie des Sciences*, June 5, 1899.

H. Le Chatelier * observes that the determination of the extensibility of iron at high temperatures had not been fully dealt with. He has, therefore, in conjunction with Chantepic, made further investigations in this direction. After describing his mirror method adopted in the determination of the elongations, he observes that as regards the expansion of irons and steels when heated, it is necessary to distinguish three periods. The first corresponds to temperatures below that at which molecular changes commence; the second to the period during such transformation; and the third to temperatures above these.

Dealing with the first of these, the author states that an ingot iron with which he experimented had the composition—

| Carbon. | Manganese. | Silicon. |
|---|---|---|
| 0·057 | 0·13 | 0·05 |

For test-pieces 100 millimetres in length the elongation in parts of a millimetre was as follows for intervals of 100° C. :—

| Temperature. | Elongation. | True Coefficient of Expansion. |
|---|---|---|
| ° C. | Millimetre. | |
| 100 | 0·110 | 11 |
| 200 | 0·230 | 12 |
| 300 | 0·360 | 13 |
| 400 | 0·500 | 14 |
| 500 | 0·650 | 15 |
| 600 | 0·810 | 16 |
| 700 | 0·975 | 16·5 |
| 800 | 1·125 | 15 |

Experiments with steel gave almost identical results. The steels experimented with contained per cent. :—

| | I. | II. | III. | IV. | V. | VI. |
|---|---|---|---|---|---|---|
| Carbon . . . . . | 0·205 | 0·49 | 0·84 | 1·21 | 0·80 | 0·75 |
| Manganese . . . | 0·150 | 0·24 | 0·24 | 0·24 | 0·15 | 0·15 |
| Silicon . . . . . | 0·080 | 0·05 | 0·14 | 0·14 | 0·06 | 0·06 |

The variations indeed were only those which lay within the limits of accuracy of the experiments. It would, therefore, appear that irons and steels have practically identical coefficients of expansion, and that

---

* *Comptes Rendus de l'Académie des Sciences*, August 7, 1899; *Echo des Mines et de la Métallurgie*, 1899, pp. 5782–5783.

they are about 0·000011 at ordinary temperatures, increasing regularly to a temperature of 785° C., when the true coefficient is 0·000017. The average coefficient between 0° and 750° is, therefore, 0·000014. At temperatures above these, at which molecular changes in the metal occur, the expansion of different varieties of steel differs considerably, according to their carbon contents, increasing with the percentage of the carbon. With regard to the expansion during the period of molecular change, the author's results varied very greatly from one another, and were often not at all concordant. This may, perhaps, be due to a complex condition of affairs, the molecular transformation of the iron resulting in a contraction of the metal, while the solution of the iron carbide in the altered metal is accompanied by an expansion which, for a steel with 0·9 per cent. of carbon, approximately agrees with the contraction due to molecular change. The author gives the results he has obtained, and intends to make additional experiments.

R. A. Hadfield * discusses the influence of casting temperature on steel, and shows how narrow are the limits within which lie success or failure. A difference of 100 lbs. of cold scrap in a 7-ton bath causes the temperature to vary 16° to 20° C., a variation perceptible to the eye, while 500 lbs. excess or deficit will make the charge too cold or too hot to cast properly. Crucible steel cast too hot has a peculiar appearance known as "scalded," and must be remelted. The use of pyrometers is referred to, and the following table is given :—

| | Deg. C. |
|---|---|
| Melting-point of sulphur | 448 |
| ,, ,, gold | 1045 |
| ,, ,, palladium | 1500 |
| ,, ,, platinum | 1775 |
| ,, ,, white Swedish iron (4 per cent. carbon) | 1135 |
| ,, ,, grey foundry-iron (3½ per cent. C., 1¾ per cent. Si., ½ per cent. P.) | 1220 |
| ,, ,, soft steel (0·10 per cent. C.) | 1475 |
| ,, ,, hard steel (0·30 per cent. C.) | 1455 |
| ,, ,, ,, (0·90 per cent. C.) | 1410 |
| 6-ton converter— | |
| In the ladle | 1640 |
| In the ingot mould | 1580 |
| Ingot in reheating furnace | 1200 |
| Ingot under steam-hammer | 1080 |
| Open-hearth furnace (steel containing about 0·30 per cent. C.)— | |
| End of fusion period of cast iron | 1420 |
| Refining-point of the steel | 1500 |

---

* *Minutes of Proceedings of the Institution of Civil Engineers*, vol. cxxxviii. pp. 442–445.

| | Deg. C. |
|---|---|
| Steel in the ladle (commencement) | 1580 |
| ,, ,, ,, (end) | 1490 |
| Temperature of gas from producer | 720 |
| ,, at the entrance to the regenerator | 400 |
| ,, when leaving the regenerator | 1200 |
| ,, ,, arriving at the chimney-stack | 300 |
| Open-hearth furnace | 1600 |
| Rotating puddling-furnace | 1230 to 1330 |
| Blast-furnace working on grey Bessemer, near tuyeres | 1930 |
| Commencement of the blast | 1400 |
| End of the blast | 1570 |

**Iron Alloys.**—The fifth report to the Alloys Research Committee by Sir William C. Roberts-Austen* deals mainly with iron. In the course of the last report, an attempt was made to connect the freezing-point curves of carburised iron with those of ordinary alloys. The series of reports as a whole has shown that alloys behave like saline solutions. It will be evident, therefore, that if carburised iron—that is, steel and cast iron—can be brought into line with ordinary solutions, a point of the utmost metallurgical importance will be gained. The series of results plotted in the last report made it quite clear that the analogy of steel to an ordinary solution of salt is of the closest possible character, even if the evidence only rests on cooling curves taken in the usual way.

It was, however, certain that the question is one of great complexity, and that a far more delicate method than the one hitherto in use must be adopted if conclusive and trustworthy results are to be obtained. The recording pyrometer has therefore been rendered more sensitive, and the improvements are described in some detail.

The cooling curves of a small mass of electrolytically deposited iron are first investigated at length, and show three hitherto unobserved points. These are shown to be due, at least in part, to hydrogen, and to its effect on the iron, and that the relations between iron and hydrogen are far more complicated than has been supposed. These are dealt with at some length, and further investigation is in hand. After reviewing generally the nature of salt solutions and eutectics, the author reverts to carbon iron solution, and gives a table showing over twenty chemical analyses, made by F. W. Harbord, of steel samples taken at intervals of thirty minutes, during the working of a hæmatite charge in a basic open-hearth furnace at the Brymbo Works, producing low carbon steel. The mechanical properties of carburised iron are then considered in relation to the solubility or freezing-point curves, and then the microscopic evidence for regarding carburised iron as a solution is discussed, especially in the light of the series of steels mentioned above, of which numerous photomicrographs are given. Other illustrations are given to show the effect of thermal treatment on rail steel, die steel, and chrome steel, all these being described in some detail. Much discussion ensued.

---

* *Proceedings of the Institution of Mechanical Engineers*, 1899, pp. 35-102; with twenty-three plates.

Marschick* summarises the results of recent researches on the preparation and properties of alloys of iron with nickel, chromium, aluminium, manganese, tungsten, molybdenum, boron, and vanadium.

**Alloys of Iron and Nickel.**—In a paper read before the Institution of Civil Engineers,† R. A. Hadfield dealt first with the physical data relating to nickel and iron; the preparation of the nickel-iron alloys and specimens; the mechanical tests upon the various cast and forged specimens; the comparison of mechanical tests upon previous alloys; the magnetic and electric qualities, and the thermal, welding, self-hardening, and corrosive tests. The second part dealt with general considerations regarding nickel-steel and its uses; and the third with the early history of nickel; the early experiments in alloying nickel and iron; meteoric iron; compounds of nickel; nickel ores and their mining, and the extraction and treatment of nickel ores. The effect upon iron of gradually increasing amounts of certain added foreign elements had already been investigated by the author in experiments upon the mechanical and physical properties of alloys of iron and manganese, silicon, aluminium, and chromium, both in the cast and forged conditions. In the present paper were given the results of a similar investigation of the alloys of iron and nickel. In a research of this nature it was important to avoid as far as possible the disturbing influences of a second foreign element, especially carbon, and this had been done as far as possible. The addition of nickel, either by conferring greater homogeneity or by some particular combination with the iron or carbon present, or both, appears to confer properties upon the alloy equivalent to annealing, or, if annealing be employed, to reduce the strain produced by forging. It did this even in the annealed material without injuring or seriously lowering the elastic limit. In this respect, therefore, its presence was of considerable utility. It would appear there was considerable room for improving the material of propeller shafts. As many as four large steamers were not long since disabled in this way in one week, and the annual record of fractures was startling in its magnitude. Was it possible that no stimulus could be found to make shipowners take measures to prevent the constantly-repeated failures of one of the vital organs of a ship? A steel propeller shaft was not so good as an iron one. An extended use of nickel-steel might be found to obviate the serious difficulty met with. The well-known Russian metallurgist, Chernoff, had stated that steel was composed of crystals of metallic iron cemented by carbide of iron, the result being that in the case of nickel-iron alloys the inter-crystalline spaces (a subject which had been fully and carefully investigated by T. Andrews as regards ordinary steel) were much more completely filled, and the cohesion consequently rendered more powerful. The points of solidification of the cement and crystals were nearer, thus producing or maintaining a more intimate interweaving of the elements. In support of this theory might be cited the fact that without doubt nickel-iron alloys showed less tendency to segregation, which apparently showed that the combinations formed at high temperature were more intimately maintained when the alloy cooled and became solidified than was the case with ordinary steel. That scientific evolution disregarded nationalities was well illustrated in the case of the metal nickel and its developments. Cronstedt conceived the idea that the deceptive kupfernickel was a metal containing a new element; from him it passed to other Swedish scientists, thence to those of German, French, and other nationalities. Attempts had been made by Faraday to produce meteoric iron artificially; similar efforts were afterwards made in France, Germany, and elsewhere. Apparently a period of inactivity followed, during which, however, first one and then another experimenter added facts to the general stock. Finally, as regards the metallurgy of nickel as applied to iron and steel, Marbeau, in France, applied the matter experimentally; Schneider, in France, perfected its application to a number of purposes, chiefly armour-plates; Riley brought the manufacture to a practical issue in England; American and Canadian enterprise followed in the perfecting of cheaper methods of producing nickel, and a new produce—nickel-steel—appeared. It had taken about 125 years to arrive at the stage reached to-day. No one person, no one nationality, could lay claim to its discovery or to its inception.

---

* *Technische Blätter*, 1898, pp. 104–120.

† *Minutes of Proceedings*, vol. cxxx. pp. 1–167.

W. F. Barrett * discusses the remarkable thermo-electric behaviour

---

* Paper read before the Royal Dublin Society, February 22; *Nature*, vol. lix. p. 502.

of certain alloys of nickel-steel. In the course of an examination of the physical properties of numerous alloys of steel prepared by R. A. Hadfield of the Hecla Steelworks of Sheffield, the author found the thermo-electric behaviour of some of these alloys so remarkable as to be worthy of a separate note. Two alloys of nickel and manganese steel marked 1414A and 1414B, which had the enormous electric resistance of 90·6 and 97·5 microhms per cubic centimetre respectively, were found to give an almost constant electro-motive force through a wide range of temperature when coupled with iron as the second metal. In the case of 1414B coupled with the purest commercial iron, the electro-motive force rose rapidly up to the temperature of 300° C., and then remained practically constant up to 800° C., a range of 500° C., that is, from a low black heat up to a bright red heat. Such a couple would form a new standard of electro-motive force, as it is easily made, and simply requires heating in any gas flame. Coupled with platinum instead of iron, these alloys give an increasing electro-motive force from about 200° C. to a white heat, the direction of the electro-motive force changing below 200° C. The second part of the paper deals with the curve of the electro-motive force on cooling, which is found to be not coincident with that on heating in the case of iron and steel coupled with platinum. At corresponding temperatures a lower electro-motive force is noticed in cooling than in heating, the difference being least marked with pure iron and most with steel, the temperature ranging from 0° to 900° C. The heating and cooling thermo-electric curves thus enclose an area which represents the molecular work done on the iron and steel during the cycle. This may be connected with the phenomena of recalescence. In the case of a couple of 1414B and platinum, the cooling curve, however, shows a higher electro-motive force than the heating curve at corresponding temperatures. The author is continuing his investigations on these and other points.

W. H. Warren * and S. H. Barraclough summarise various published statements on nickel-steel, and give the result of their own tests on three varieties, viz., mild, with 3 per cent. of nickel; medium, with 8 per cent., and non-rusting, with 25 per cent. Detailed figures are given for tensile, torsion, compression, and shearing tests, and also for liability to corrosion. For comparison, similar tests are given of axle steel. The limits of elasticity for the three nickel-steels in tension are

---

* *Journal and Proceedings of the Royal Society of New South Wales*, vol. xxxii, pp. 150–168.

given as 19·2, 23·75, and 13·10 tons respectively, and in compression the elastic limits are 14·5, 13·1, and 11·99 tons respectively.

C. E. Guillaume* has published an article on the temporary and residual variations in reversible nickel-steel alloys, in which he gives a continuation of the experiments upon nickel-steel alloys, with especial reference to the construction of standards.

Heller† refers to some nickel-steel which proved when delivered to be so hard that it could not be worked up at all, this only becoming possible after the steel had been submitted to special treatment, details of which are not given. In contradiction to the reputed non-oxidisability of nickel-steel, this sample rusted very rapidly.

A. F. Yarrow‡ gives the results of some experiments on nickel-steel, having reference to the durability of water-tube boilers. In dilute hydrochloric acid, mild steel lost on the average 16½ times as much weight as nickel-steel containing 20 to 25 per cent. of nickel. On exposure to fire under similar conditions, the loss was three times as much. Other tests were made by passing steam through tubes heated on the exterior, in order to reproduce boiler conditions to some extent, with the result that the nickel alloy outlasted 2⅓ mild steel tubes. At lower temperatures than bright red the advantage was more marked. The difference in the coefficient of expansion renders it inadvisable to use the two metals side by side in the same boiler. Other advantages of nickel-steel include its greater physical strength.

**Radiographic Examination of Steel Plates.**—J. Daniel§ gives the results of an examination of steel plates intended for boiler tubes by means of the Röntgen rays. No conclusions can be drawn from the experiments described, but the matter is one of considerable interest, and practical results may be anticipated from the radiographic examination of a sufficiently large number of well-selected samples.

**The Effect of Punching and Shearing.**—Further accounts of C. Fremont's‖ experiments on the effect of punching and shearing on metals have appeared. Plates were submitted to the action of a punch, of which the stroke was varied so as to partially and to completely penetrate, and sections of the punched plates were cut, polished, and etched to show the fibres. The superficial layers are submitted to a shearing strain, while a tensile strain seems to be the most important in the middle layers. The surface of fracture is not cylindrical, but is formed by a pair of conical surfaces, the smallest diameter corresponding with the middle of the plate. The phenomena exhibited by the punching of a solid plate differ from those obtained from a series of thin plates, in which the various layers are free to slide on each other. Diagrams and photographic reproductions are appended.

---

* *Comptes Rendus de l'Académie des Sciences*, July 17, 1899.

† *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. p. 555.

‡ *Transactions of the Institution of Naval Architects*, vol. xli. pp. 333–346.

§ *Annales des Mines de Belgique*, vol. iv. pp. 528–532.

‖ *Mitteilungen aus der Praxis des Dampfkessel- und Dampfmaschinen-Betriebes*, 1899, p. 244.

**Torsion and Recalescence of Steel.**—G. Moreau,[*] in some experiments on the torsion of steel wire, finds that the formula expressing the result contains a constant which varies very rapidly in the neighbourhood of the point of recalescence and of maximum hardening, and thus furnishes a new means of determining these two points exactly. It retains its initial value up to 290° C., and then diminishes up to the temperature of recalescence, 715°, after which it remains constant.

**Eolotropy in Steel.**—T. Gray[†] gives a note on what he terms eolotropy in steel. A flat bar 0·41 inch wide by 0·063 inch thick, heated in a smithy fire and slowly air-cooled, showed, when bent like a flat spring, an elastic limit three times as great in one direction as in the other. Probably one side had been converted into cast iron, with higher elastic strength in compression than in tension.

**Internal Strains in Steel.**—The results of a large number of experiments have been published[‡] to show the internal strains in a 3-inch single forging gun and in a 5-inch gun. The forging was heated and quenched from the bore in each case. Slices were taken from the muzzles and breeches, and were cut into annular rings in the usual way and their diameters taken. The results are given in detail.

**Testing Machines.**—W. H. Warren[§] gives illustrations of a machine used in the University of New South Wales for testing three specimens at once under alternating stresses. The test-pieces are screwed to revolving spindles, and bear on two V-shaped supports, of which the distance apart is adjustable. The free end of each specimen is loaded.

---

[*] *Comptes Rendus de l'Académie des Sciences*, vol. cxxviii. pp. 292–294.

[†] *Proceedings of the American Association for the Advancement of Science*, vol. xlvii. pp. 250–251.

[‡] *Report of the Tests of Metals*, Washington, 1899, pp. 211–241.

[§] *Journal and Proceedings of the Royal Society of New South Wales*, vol. xxxii. pp. cxxix–cxxxi.

M. Merriman,* in a presidential address to the American Section of the International Association for testing materials, gives a short history of the subject, dealing more particularly with the work of the International Association.

**Standard Tests of Cast Iron.**—The Committee appointed by the American Foundrymen's Association have issued a report † on their progress in standardising the testing of cast iron, and this report contains full details of the very numerous tests made of test-pieces of different sizes and materials prepared under similar conditions. Up to the present, 667 test-bars have been cast and 943 test-pieces made, of which 456 were machined. The total number of tests made has been 1015. Three sets of tests have been made and two more are in hand. The tests made include tensile tests on bars up to 4 square inches in section, transverse tests on bars up to 16 square inches in section on supports 12 inches apart, compression tests on ½-inch cubes, chemical analyses, fluidity tests, chilling tests, and contraction tests. Impact tests were omitted, as no reliable means for testing are available, but it is intended to take the cooling curves. The three sets of tests made are on iron of the following analyses, and denominated A, ingot mould iron, soft Bessemer mixture; B, dynamo-frame iron; C, light machinery iron:—

| | Total Carbon. | Graphite. | Silicon. | Manganese. | Phosphorus. | Sulphur. |
|---|---|---|---|---|---|---|
| A. | 3·87 | 3·44 | 1·67 | 0·29 | 0·095 | 0·032 |
| B. | 3·82 | 3·23 | 1·95 | 0·39 | 0·405 | 0·042 |
| C. | 3·84 | 3·52 | 2·04 | 0·39 | 0·578 | 0·044 |

A. Ledebur ‡ gives a critical summary of this report.

The method of casting the test-bars by T. D. West § is given as an appendix with many illustrations, and is followed by the full details of the results of the tests, 847 in number. Illustrations are appended of the fracture of each kind of iron to show the chill, &c. At present the results have not yet been summarised.

---

* *Engineering News*, vol. xlii. pp. 99-100.

† *Journal of the American Foundrymen's Association*, vol. vi. pp. 119-175.

‡ *Stahl und Eisen*, vol. xix. pp. 718-721.

§ *Ibid.*, pp. 127-141.

The composition of a large number of cupola and air-furnace charges are given* together with analyses of the castings, the tensile tests, and specific gravities as determined at Watertown Arsenal.

Berger† gives the results of an elaborate series of experiments on the pressure elasticity of cast iron.

C. Bach‡ has made an extended series of experiments on chilled cast iron under tensile, transverse, and compression tests, and the results showing the modulus of elasticity are fully set forth.

S. Bent Russell§ illustrates and describes tests made by a new method under which the specimens were broken by tensile stress, giving results.

T. D. West|| shows that impact tests of test-pieces must be used with care in determining the power of castings to resist shock. Thick and thin parts of the castings contract unequally, and thereby set up strains which considerably affect the strength.

**Transverse Tests of Cast Iron.**—B. Moldenke¶ has experimented upon the influence of the length of span in transverse tests of cast iron. Several sets of bars 2 inches square and 16 inches long were cast vertically, and were tested on different spans at the same speed, with the following results:—

| Average Cross Section, inches. | | Supports Apart. | Average Breaking Strain. | Average Modulus of Rupture. | Average Deflection. |
|---|---|---|---|---|---|
| Depth. | Width. | Inches. | Lbs. | Lbs. per sq. inch. | Inches. |
| 1·96 | 2·02 | 6 | 34,650 | 40,000 | 0·063 |
| 1·96 | 2·00 | 8 | 25,100 | 39,070 | 0·070 |
| 1·98 | 2·00 | 10 | 18,720 | 35,660 | 0·064 |
| 2·00 | 1·99 | 12 | 16,380 | 36,970 | 0·080 |
| 2·00 | 1·98 | 14 | 13,560 | 35,900 | 0·094 |
| 1·99 | 1·99 | 16 | 11,370 | 34,380 | 0·096 |

The fall in the modulus is fairly uniform except at the 10-inch span. This occurred in all the sets, and its reason is not clear. The

---

* *Report of the Tests of Metals*, Washington, 1899, pp. 353-369.

† *Mittheilungen des Gewerbe Museums*, Vienna, 1899, pp. 219-235.

‡ *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. pp. 857-866.

§ *Proceedings of the American Society of Civil Engineers*, vol. xxv. pp. 354-369.

|| Paper read before the American Section of the International Association for Testing Materials, August 1899.

¶ *Engineering News*, vol. xlii. p. 103.

change in the modulus may be affected by the relative proportions and by the composition, and does not agree with accepted formula for calculating it. The shock resisting power is often taken as half the product of the breaking load and deflection, divided by the weight of the bar between the supports, but in the above instances the figures so obtained range from 176 to 33.

**Tests of Steel.**—Particulars are given of the tensile tests and composition of the metal used in the Atbara bridge.*

As usual, a very large number of tests of steel for ordnance and other purposes are given in the report of the work at Watertown Arsenal.†

W. K. Hatt ‡ read a paper on the comparison of steel plates under flexure and tension. It is pointed out by many duplicate tests that the tenacity as well as proportional limit and yield point are not the same when determined from tension and tension tests. In a certain steel plate 12 inches by 1¾ inch the proportional limit and yield points were unusually low, in fact, only about 17,000 lbs. and 25,000 lbs. per square inch, from repeated tests, while all other properties were apparently normal. Much discussion followed.

Rasch § gives the results of tests of cast steel balls made at the testing station of the Bavarian Commercial Museum.

C. Bach ‖ gives the results of some mechanical tests of bars of cast steel. These were very satisfactory, and the author considers them to show that metal of this kind is a most useful material.

**Testing Bicycle Tubing.**—O. Smith ¶ describes a simple form of lever machine for testing bicycle tubing under compression, either by bending, crushing, or splitting. A number of tests of several sizes of tubes made in different ways are given, showing the load and distortion. Some tubes made with the drawing-press simply, and not further submitted to the draw-bench, gave good results. A spindle in ball bearings is used in place of knife edges as a support for the lever in the testing-machine.

---

* *Engineering*, vol. lxvii. p. 772.

† *Report of Tests of Metals*, Washington, 1899.

‡ Paper read before the American Section of the International Association for Testing Materials.

§ *Zeitung für Werkzeugen*, 1899, pp. 301–303.

‖ *Zeitschrift des Vereines Deutscher Ingenieure*, vol. xliii. pp. 694–696.

¶ *Iron Age*, August 3, 1899, pp. 10–11.

**Test of a Wire Rope.**—A. Martens * describes the testing of a wire rope 3½ inches outside diameter. The rope consisted of a central core and six principal strands, each having a hemp core and six secondary strands laid with thirty wires in two layers of eighteen and twelve round a hemp core, or 1080 wires in all, each 0·058 inch in diameter. The tensile strength of the wire was 116 tons per square inch, and the rope ultimately broke near the end of the splice with a load of about 250 tons, or three-quarters of the total breaking strength of all the wires, which was 330 tons.

**Wheels.**—G. R. Henderson † gives the following analyses of wheels—

| | Which stood thermal test for 60 months. | | Which stood 40 or more blows drop test. | | Which gave 5 or more years of service. | | Which gave 8 to 11 years service. | | Desirable limits. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Max. | Min. | Max. | Min. | Min. | Max. | Min. | Max. |
| Graphite | 3·28 | 2·65 | 3·31 | 2·65 | 3·18 | 2·23 | 2·75 | 3·00 | 2·56 | 3·10 |
| Combined carbon | 0·95 | 0·32 | 0·90 | 0·55 | 1·24 | 0·56 | 0·50 | 0·75 | 0·63 | 1·01 |
| Silicon | 0·75 | 0·50 | 0·70 | 0·50 | 0·94 | 0·58 | 0·50 | 0·70 | 0·58 | 0·68 |
| Manganese | 0·53 | 0·20 | 0·46 | 0·24 | 0·34 | 0·13 | 0·30 | 0·50 | 0·15 | 0·27 |
| Sulphur | 0·088 | 0·055 | 0·086 | 0·040 | 0·085 | 0·047 | 0·05 | 0·07 | 0·05 | 0·08 |
| Phosphorus | 0·48 | 0·35 | 0·52 | 0·36 | 0·49 | 0·25 | 0·35 | 0·45 | 0·25 | 0·45 |

Specifications for the manufacture of wheels are given, and their manufacture generally is considered.

**Rails.**—A. T. Moxham ‡ gives the results of some experiments on the wear of rails subject to heavy wear for three years on an electric tramway in Brooklyn. The details may be tabulated as follows :—

| | Carbon per Cent. | Specific Gravity. | Tensile Strength. | Average Monthly Wear. |
|---|---|---|---|---|
| | | | Lbs. | Inch. |
| Soft rail | 0·28 | 7·956 | 75,860 | 0·0017 |
| Hard rail | 0·59 | 7·971 | 118,100 | 0·0012 |
| Hard and ductile rail | 0·57 | 7·977 | 120,380 | 0·0007 |

The experiments prove that almost any steel will last longer than the joints can be maintained in good condition.

---

* *Mittheilungen aus den königlichen technischen Versuchsanstalten zu Berlin*, vol. xvi. pp. 89-93.

† Paper read before the American Foundrymen's Association, May 1899.

‡ *Electrical Engineer*, New York, vol. xxvi. pp. 459-460.

According to a recent report,* eight railways in the United States are using 45 and 60 foot rails, but as yet they are not considered altogether satisfactory in comparison with the ordinary length of 30 feet. The main drawback arises from the difficulty in straightening the longer rails, and another objection is due to the increased opening required for expansion. Thirty-three foot rails are recommended as reducing the number of joints by 10 per cent. Mitre-cut rails are not considered satisfactory, though two railways using rails with their ends cut at an angle of 55° are fairly satisfied, but, on the other hand, several railways have reverted to square cut ends.

An illustration has appeared † of an 80-lb. rail containing 0·48 per cent. of carbon which has been subjected to heavy wear on an electric railway. Most of the head has disappeared.

M. K. Bowen ‡ discusses rails and rail-joints especially for electric tramways. The form of the rails before and after wear, and cast joints are considered.

**Tests of Armour-Plates.**—Entire satisfaction is expressed by officers of the Bureau of Ordnance with the ballistic tests of the 15-inch nickel-steel Harveyised plate recently at the Naval Proving Station, Indian Head. This plate was attacked twice by a 10-inch gun at different velocities, and while one of the shots penetrated, this was expected and caused no surprise. The results obtained were so satisfactory that the entire group of armour represented by the plate has been accepted by the Government. The report of the officers conducting the trial presents these facts:—The powder charge used weighed 172 lbs., which gave the Carpenter 10-inch uncapped shell a velocity of 1513 feet per second. At the first shot the impact was 57 inches from the bottom of the plate and 75 inches from the right edge. This projectile smashed on the plate, the head remaining welded in. The estimated penetration was 9 inches, and the diameter of the hole 11·75. There were no cracks in the plate. The powder used was brown prismatic. On the second round smokeless powder was used, the charge being 139 lbs., producing a velocity of 1093 feet per second. The projectile was a 500-lb. Carpenter, the impact being 50 inches from the bottom and 36 from the right edge. The projectile smashed on the plate, the head remaining welded in.

---

* Paper read before the Roadmasters' Association of America, September 1899; *American Manufacturer*, vol. lxv. p. 251.

† *Engineering News*, vol. xlii. p. 213.

‡ *Cassier's Magazine*, vol. xvi. pp. 425–432.

The penetration was 17 inches, which includes the back bulge. The diameter of the hole was 12 inches. There were three slight surface cracks extending from the right edge, but only about skin-deep. The plate attacked was what is known as the nickel-steel, re-forged and face-hardened variety, backed by 12 inches of oak. Navy Ordnance officers regard the test as somewhat below the usual results, but it was sufficiently good to ensure the acceptance of 700 tons of armour represented by it.*

On September 1, 1899, a Vickers plate for the Japanese armour-clad *Shikishima* was tested at Whale Island by three rounds from a 9·2-inch gun with a 380-lb. Holtzer armour-piercing steel shot. The striking velocities were 1700, 1700, and 1800 foot-seconds, and the penetration 3 inches, 3 inches, and 3¾ inches, no cracks being developed.†

Experiments have lately been concluded at Shoeburyness ‡ with some samples of a new kind of armour-plate, six inches of which is of ordinary steel and 3 inches of a special composition, the nature of which is not made public. These plates have been fired at with a 350-lb. projectile at a distance of 200 yards. When black powder was used, the plate was practically uninjured after several shots, and in some cases the projectile was reduced to dust by the force of the impact. With cordite it was found that the plate could be penetrated for about 3 inches, or even pierced; but the severest tests failed to cause the plate to crack. Two shots were then fired at a plate simultaneouly, striking the plate a foot apart, but still the composition was not fractured. The plate was then fired at obliquely, when it was found that the special facing split from the steel backing, although the welding was previously invisible to the eye.

---

* *Journal of the Royal United Service Institution*, vol. xliii. p. 1035.

† *Engineer*, vol. lxxxviii. p. 238.

‡ *Journal of the Royal United Service Institution*, vol. xliii. p. 1019.

# CHEMICAL PROPERTIES.

**The Rusting of Iron.**—W. R. Dunstan [*] gives the results of his experiments to determine the cause of rusting of iron. In the presence of dry oxygen, water vapour, liquid water, oxygen and water vapour, no rusting occurs; but iron rusts when it is exposed to the simultaneous action of liquid water and oxygen. Care was taken to exclude carbonic anhydride, which is thus shown not to play a necessary part in rusting. As liquid water is necessary for rusting, and alkaline salts prevent it, hydrogen peroxide seems to play an important part in the formation, and further experiments show that this is so, as substances which prevent the formation of the hydroxyl also prevent rusting. The reactions that occur are probably—

$$Fe+H_2O+O_2=FeO+H_2O_2$$
$$2FeO+H_2O_2=2FeO(OH)_2.$$

The action is partly, if not wholly, electrical in its origin. Steel rusts less than iron, and observations of the microstructure showed that the ferrite or pure iron was attacked, but not the carbide constituents.

**The Corrosion of Iron.**—H. P. Brown [†] states that cast iron pipes are usually but little affected by electrolysis by the current from electric tramways, since the coating of adherent moulding sand and tar paint protects them. In one case, however, the surface of the pipe was changed into a soft black material resembling graphite, and easily cut with a knife. The chemical analysis of the pipes shows that the percentage of iron is greatly diminished, while the percentage of carbon is more than doubled.

The results of a number of tests of different paints, in regard to their protective action on iron in water, have been published.[‡] The great superiority of paints containing red or orange lead is shown, but zinc oxide follows closely, and barytes takes a higher position than is generally supposed.

---

[*] *Proceedings of the Royal Artillery Institution*, vol. xxvi. pp. 255–265.

[†] *Electrical Engineer*, New York, vol. xxvi. 1898, pp. 441–442.

[‡] *Engineer*, vol. lxxxviii. pp. 29–30.

**Action of Sea-Water on Iron.**—A number of metallic articles which have been dredged up from the sea at Brest have been examined by Ledy.* Only gold and silver had remained intact. Pure bronze only containing traces of lead, iron, and zinc had shown great resistance to the action of the sea-water, having only undergone slight superficial corrosion. Wrought and cast iron, on the other hand, had been greatly acted on, not only at the surfaces of the objects, but throughout the mass of the metal. In the case of wrought iron the action has been greatest at the surface of the metal, while in the case of cast iron it is not the surface, but the interior of the metal which has suffered most. It may subsequently be cut with a knife, just like lead, although the actual shape has remained unchanged. The action is more or less complete according to the composition of the pig iron and the time of exposure.

**Action of Water on Galvanised Iron.**—According to Herbert E. Davies,† all kinds of water attack zinc or galvanised iron in the presence of air. Distilled or rain water has a decided solvent action, although after a time the greater part of the metal is reprecipitated. Hard waters dissolve a larger quantity, in which respect zinc differs from lead. When the metal gets gradually coated with hydrated zinc carbonate, the action is not altogether stopped, and the water may still contain 0·3 part of zinc per 100,000.

**Ferrosilicon.**—G. de Chalmot ‡ observes that in the blast-furnace it is only possible to make a ferrosilicon containing some 11 or 13 per cent. of silicon, while in the electric furnace alloys are obtained which contain up to 50 per cent. Analyses point to all these alloys being mixtures of two well-defined alloys of iron and silicon, having the formula $Fe_3Si_2$ and $FeSi_2$. On solution in hydrofluoric acid $Fe_3Si_2$ dissolves the more readily. The residue obtained by interrupting the solution suitably is represented by the formula $FeSi_2$. Ferrosilicon is crystalline in structure, and with from 25 to 30 per cent. of silicon takes a good polish and has a silvery lustre. The melting-point increases with the increase in the percentage of silicon. These latter kinds show scarcely any magnetic properties, a further proof that no free iron is present in the alloys. With increasing percentages of silicon, the solubility of the alloys in nitro-hydrochloric acid diminishes, while the solubility in caustic soda increases. All these alloys resist strongly oxidising agents, and are good conductors of electricity. They are consequently good and cheap materials for anodes in electrolytic processes. Ferrosilicon can be readily cast.

---

* *Annales des Ponts et Chaussées; Echo des Mines et de la Métallurgie*, 1899, p. 5719.

† *Journal of the Society of Chemical Industry*, vol. xviii. pp. 102–105.

‡ *Journal of the American Chemical Society*, vol. xxi. p. 59.

P. Lebeau * finds that silicide of iron is soluble in silicide of copper, and crystallises out on cooling. By melting 40 grammes of iron filings with 100 grammes of commercial copper silicide in a graphite crucible, with a current of 950 amperes at 45 volts, a crystalline product is produced, and the silicide of copper can be dissolved out by nitric acid, leaving silicide of iron free from carbon and phosphorus.

**Aluminium as a Reducing and Heating Agent.**—H. Goldschmidt † gives a further account ‡ of the use of aluminium for producing metals such as iron, chromium, manganese, &c., in a pure state, and for generating a temperature up to about 3000° C., which is sufficient to melt chromium, hitherto only melted in the electric arc.

Pure chromium can be produced by this process much cheaper than ferrochrome by the ordinary methods; 100 kilogrammes (220 lbs.) of chromium can be separated in twenty-five minutes. The great heat produced can be easily applied to such processes as brazing and welding, production of alloys, *e.g.* iron and titanium, local heating of metal parts, &c. Three men can carry out the operation of welding rails in place by this method, no heavy apparatus being required.

F. Kupelwieser § discusses the Goldschmidt method for the production of high temperatures and the reduction and preparation of metals free from carbon. This depends on the use of aluminium as the reducing agent. Aluminium not only burns in the air, but if the temperature of combustion exists, it will also burn at the expense of the oxygen in the oxides of other metals, reducing these to the metallic state. Aluminium has a high calorific power, yielding 7140 calories, and this is adequate in very many cases not only to reduce a metal, but to fuse it into a button and separate it from the slag. The method has the great advantage that, no carbon being used, the reduced metals are free from that element, and pure metals can be obtained. Fireclay crucibles are used, lined preferably with a layer of magnesia, and then heated high enough to drive out moisture and carbon dioxide. They are then for use placed in a box filled with sand, no heat from external sources being required, while it is also necessary to avoid loss of heat during the process. To raise the temperature of the mixture of aluminium and the oxide under treatment high enough for the reduction to commence, a kind of match is employed. This consists principally of a mixture of aluminium filings with a salt that will readily give up oxygen, such as barium peroxide, potassium chlorate, nitre, &c. This is mixed together and used in the form of powder. The crucible having been about three-fourths filled with the mixture of metallic oxide to be reduced and the aluminium for its reduction, the other lighting mixture is strewn upon it in relatively small quantity, and this is then lit by means of a similar lighting mixture made into a ball by means of a binding agent, and provided with a wick consisting of a strip of magnesium. When the mixture in the crucible has in this way been brought into activity, fresh mixture may be charged in in small quantities as the process proceeds. The reaction is very quiet if the crucible was perfectly dry, and is completed within a few minutes. The author discusses the question from a calorimetric point of view, and deals in this way with the reduction of iron, manganese, silicon, chromium, and tungsten, all free from carbon.

---

* *Iron and Coal Trades Review*, vol. lix. p. 10.

† *Verhandlungen des Vereins zur Beförderungen des Gewerbfleisses*, 1899, p. 57.

‡ *Journal of the Iron and Steel Institute*, vol. liv. p. 548.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 145–149.

It is pointed out by A. Duboin* and A. Gauthier that in Goldschmidt's experiments on the reducing action of aluminium on metallic oxides, the resulting metal is usually mixed with an excess of alumina which has been raised to a very high temperature. As this alumina is then very refractory to the action of reagents, the authors have made experiments with chlorine, bromine, and iodine on the mixtures, which result in the preparation of boron and silicon by this method. Boric acid is very readily reduced by aluminium, the reaction being of a violent character. Silica is also reduced by aluminium, but not so readily. Boron and silicon intimately mixed with this alumina were found to behave under the conditions of the test like carbon, the halogen compounds of aluminium being formed, and the boron and silicon remaining as oxides.

---

* *Comptes Rendus de l'Académie des Sciences*, vol. cxxix. pp. 217-218; *Echo des Mines et de la Métallurgie*, 1899, p. 5720.

**Science and Iron-Smelting.**—A. Ledebur,* in his inaugural address as Rector of the Freiberg Mining Academy, discusses the results obtained by scientific means in connection with iron-smelting. The Freiberg Mining Academy is the oldest of all existing mining schools, and had its origin in the preceding century, in the recognition of the fact that mining and metallurgy could never attain a really flourishing condition unless they were developed on scientific lines.

He then proceeds to consider the progress that has resulted to metallurgy, and in particular to the iron industry, as the result of scientific investigations. In prehistoric times man used various metals which occurred in their native state, such as silver, gold, and copper. The demand led to improvements in the supply, and the plan of a Nubian gold mine of the time of Rameses II. of Egypt, who lived in 1250 B.C., is still extant. Not only, however, did man learn to separate native metals from their matrix, but also how to reduce metals from their ores, and so to the above-named metals others became added, such as lead, tin, and iron. It cannot be doubted that many nations manufactured and utilised iron long before they knew of other metals, such as copper and tin, the constituents of bronze, and that the theory according to which a bronze period always preceded an iron age is untrue, at least in its general form.

The production of iron was a very simple matter. The ore was smelted down in a large heap of burning charcoal, and a mixture of slag and iron granules resulted. By treatment with the hammer the slag was separated from the iron, and a coherent mass of iron resulted, which possessed when heated great malleability, and at ordinary temperatures greater hardness and strength than any of the other metals. It was, therefore, useful for all kinds of purposes. The use of a bellows was soon discovered, and to keep the fire together a wall was built around it. In this way resulted the simple furnace methods still in use by native tribes for the reduction of malleable iron from iron ores, of which hearths are a type. Iron metallurgy remained much in this condition until, in the fourteenth century, the production of pig iron in the blast-furnace was discovered and introduced. Dealing with the ideas which were held as to what actually took place when ores were smelted, the author briefly recapitulates the history of chemistry, and then shows that it is to the results of chemical analysis that our present knowledge of iron-smelting is due. Not only has chemistry helped in this matter, however, but physics also. The measurement of temperatures became possible after a time, and the idea of specific heats was also understood. Without the discovery of a practicable steam-engine the iron industry could never have attained its present position. By the earlier decades of this century, it had been recognised that ordinary commercial iron always contained foreign constituents which influenced its behaviour, and that the most important of these was carbon. Further, that graphite was not the same as the sulphide of molybdenum, as had been previously supposed, but only a particular form of carbon, separated under special conditions, which were, however, only actually ascertained at a later date. It gradually began to be recognised that iron was separated from its ores by the elimination of oxygen, and that heated iron was capable of again taking oxygen out of the air. The desire to save fuel in the blast-furnace led to the discovery of the hot-blast, and the recognition that the flame escaping from the throat of the blast-furnace was nothing else than burning carbon monoxide led Faber du Faur at Wasseralfingen in 1837 to experiment with a view to taking away unburnt gas from the blast-furnace for heating purposes elsewhere. It was these trials that led to the complete success of the hot-blast and of the steam-engine as applied to blast-furnace practice, and it became possible both to heat the blast and to drive the engines without the consumption of any additional fuel. The difficulties that were connected with the use of the blast-furnace gas in this way led to the discovery of the separate gas-producer. With regard to the actual chemical changes that took place in the blast-furnace, nothing was actually known until in 1838 Bunsen made his first experiments with gases at a small blast-furnace in Hesse. He collected gases from various parts of the blast-furnace, and showed the connection that existed between their composition and proper smelting conditions in the blast-furnace. Subsequently there was added to this investigation of the gaseous constituents an examination of the solid ones. These were also taken from various parts of the furnace, and the question of the melting-points of slags was also dealt with by various experimenters. In this way blast-furnace practice, which up to then had been purely empiric, began to be carried on on more and more scientific lines. From the composition of the materials to be smelted, calculations were made in advance of the materials required to produce a pig iron of a particular composition, and these took the place of the blind attempts which were previously all that was possible. But they went even further than this, and the question as to how the heat added to the furnace by the blast or produced there was utilised began to be intelligently followed. It was recognised that certain amounts of heat were necessary for the reduction and for the decomposition of carbonates and hydroxides, and for fusion purposes, and that these were capable of calculation, and also that heat was lost in the furnace gases. The result of all this has been that the fuel now actually consumed in the blast-furnace is not greatly in excess of that theoretically required. Research was also being carried on in other directions, and the author briefly refers to the rise of the Bessemer process. It was at first thought that it was the carbon in the pig iron which was the source of heat in the Bessemer process, and it was with astonishment that it was observed that the pig iron richest in carbon was often the one which gave the worst results. It was only when a scientific investigation of the subject was undertaken that the part which silicon plays was fully understood. Not until twenty years had elapsed was the basic Bessemer process thought out, and the influence and behaviour of phosphorus rightly known. Up to then phosphorus had been the greatest enemy of the iron-smelter, while now it is looked upon as a valuable constituent of iron ore. What all these results of science have meant in national life, and how enormous have been the changes which they have brought about, need not be pointed out.

---

* *Stahl und Eisen*, vol. xix. pp. 757–760.

# CHEMICAL ANALYSIS.

## *CONTENTS.*

| | | PAGE | | | PAGE |
|---|---|---|---|---|---|
| I. | Analysis of Iron and Steel | 480 | III. | Fuel Analysis | 492 |
| II. | Analysis of Iron Ores and Slag | 489 | IV. | Gas Analysis | 493 |

## I.—*ANALYSIS OF IRON AND STEEL.*

**Metallurgical Analysis.**—A. L. Colby [*] gives a bibliography of books dealing with analysis in its various branches, as it affects the chemist at iron and steel works. No less than 112 books are mentioned under eleven headings, and of these, twenty-six books are recommended as those which should be in the library of the professional chemist. The others are either elementary treatises or are otherwise unsuitable. The author's selection comprises books on quantitative analysis of iron and steel by Arnold, Blair, Lord, and reprints from the Engineers' Society of Western Pennsylvania; on general quantitative analysis by Crookes, Fresenius, Phillips, Stillman, Cairns, Cheever, Talbot, Thorpe, and Ostwald; on volumetric analysis, by Sutton; on electro-chemical analysis, by Classen and Smith; on gasometry, by Gill, Hempel, and Winkler; on fuel analysis, by Poole and Snow. In addition, various books of tables and other reference works, including the *Journal of the Iron and Steel Institute*, are recommended.

H. Paweck [†] gives a useful bibliography of recent monographs dealing generally with modern progress in electro-metallurgy and electro-

**Standards for Iron Analysis.**—A progress report of the American Foundrymen's Association Standardising Bureau has recently been issued, and contains details of the method of preparing the standards and a list of the users. A casting weighing about 500 lbs., in the form of a hollow cylinder 23 inches long, 16½ inches internal diameter, and 1½ inch in thickness, was cast from below in a dry sand mould with a dried core, an excess of 300 to 500 lbs. of metal being run through the mould to clear away dirt. The casting was then turned down in a lathe, the outer skin to the depth of ⅛ inch being turned off and rejected, and then fine turnings taken until the casting was reduced in thickness to ¼ inch. About ½ inch at the bottom and 2 inches at the head were also untouched to avoid any impurities. The turnings were made fine enough to pass a 20-mesh sieve, and were spread out and thoroughly mixed. Sample bottles holding a third of a pound were filled with great care, a portion of each scoopful from all parts of the layer being put in each bottle.*

---

[*] *Iron Age*, June 15, 1899, p. 9; June 22, p. 29; June 29, p. 15.

[†] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 494-495.

A. W. Smith † discusses the utility of chemically standardised iron samples.

E. E. Johnston ‡ gives the results of about fifty analyses made by different chemists using various methods, on samples obtained by drilling the planed face of a pig. The methods used are indicated, and the remarks made by the analysts are appended. The full results are given in tabular form, from which the following may be gleaned :—

| | Si. | P. | Mn. | S. | Combined Carbon | Graphite. | Total Carbon. |
|---|---|---|---|---|---|---|---|
| Highest . | 1·38 | 0·162 | 0·44 | 0·025 | 0·910 | 3·85 | 4·420 |
| Lowest . | 1·19 | 0·190 | 0·29 | 0·003 | 0·289 | 3·05 | 3·942 |
| Average . | 1·261 | 0·1762 | 0·34 | 0·0113 | 0·443 | 3·678 | 4·156 |

In the course of the investigation it was clearly evident that very careful sampling is requisite if uniform results are to be obtained, and in this connection some reflections are made on the samples prepared by West. To show how samples may vary, drillings were rubbed down to pass a 30-mesh sieve, and then the fine portions which passed an 80-mesh sieve were separated. Analysis of the two portions showed :—

---

* *Journal of the American Foundrymen's Association*, vol. vi. pp. 206–222.

† *Ibid.*, pp. 246–254.

‡ *Iron Age*, May 18, 1899, pp. 8–10.

| | Graphite. | Combined Carbon. | Si. | Mn. | P. | S. | Fe. |
|---|---|---|---|---|---|---|---|
| Coarse . . | 1·376 | 0·230 | 2·78 | 0·71 | 0·20 | 0·014 | 94·590 |
| Fine . . | 6·862 | 0·350 | 3·05 | 0·76 | 0·17 | 0·020 | 88·668 |

**Determination of Iron.**—V. Rouff[*] describes a modification of the Wiborgh method for the volumetric determination of iron. The method is as follows:—Half a gramme of pig iron or one gramme of steel is placed in a closed flask, and a small quantity of copper sulphate solution is added, the intention being to prevent too rapid an action by forming a deposit of copper on the iron. The solvents used are, as usual, chromic and sulphuric acids, but with the addition of phosphoric acid. This latter is a strong solvent for the various kinds of carbon present in the samples to be dealt with, and by its use it becomes unnecessary to submit the metal to any hardening process before dissolving it. The strengths of the solutions used are given. The carbon dioxide given off is determined by absorption in caustic potash.

**Determination of Carbon.**—J. Spüller[†] describes a rapid modification of the Eggertz method for the determination of carbon. The operation is effected in from twelve to fourteen minutes, and the results obtained are almost identical with those obtained by the ordinary Eggertz method, and do not differ by more than 0·03 to 0·06 per cent. from gravimetric results. The method is as follows:—Weigh off 0·1 gramme of the steel filings, and in a similar manner two samples of standard steels, or more if the carbon contents of the sample under examination is not approximately known. To each sample 5 cubic centimetres is added of pure nitric acid of 1·2 specific gravity, and they are then allowed to stand for half a minute. The samples are next placed in a paraffin bath, raised to a temperature of 135° C., and allowed to boil in this for a period of five minutes. To ensure treatment as similar as possible for all of them, they are placed in the bath in the same order as they have the acid charged into them, and are taken out again in a similar order. After this period of treatment, all red fumes have disappeared and the solutions are clear.

[*] *Bulletin de la Société de l'Industrie Minérale*, 1897, p. 883.

[†] *Chemiker Zeitung*, vol. xxiii. pp. 476–478.

The tubes are then wiped and allowed to cool for two minutes, and subsequently compared in the usual way. The use of a dark box as recommended by Eggertz gives best results.

P. W. Shimer* uses a platinum crucible in place of the ordinary porcelain or platinum combustion tube for the combustion of the residues from the solution of steel. An ordinary platinum crucible about $\frac{17}{16}$ inch in diameter at the top, and $\frac{19}{16}$ inch high is used. The top is stiffened by an exterior copper ring, and the mouth is closed by a water-cooled stopper made of sheet copper with a rubber band. The bottom of the crucible is heated by a Bunsen burner, and the crucible is partly filled with asbestos to prevent softening of the rubber by radiation. Otherwise the stopper is easily kept cool by a small water supply. The air inlet and outlet tubes pass through it, and are connected to a train of absorbing bulbs, &c., more or less of the usual type. One modification that the author employs, however, consists of a brass tube to contain the cupric oxide for completing the combustion. This tube is $\frac{3}{8}$ inch in diameter and 10 inches long, filled in the centre with the oxide, and heated for $1\frac{1}{2}$ to 2 inches by a good Bunsen burner. For obtaining the carbon from steel, the standard method of solution in acidified double chloride of copper and potassium is used, and subsequent filtration through asbestos. The preparation and use of the asbestos filter is described in detail, and with the precautions given, it is easy to arrange that all the carbon lies near the bottom of the combustion crucible, where it will be subject to the full heat. Air is successfully used in place of oxygen, but the cupric oxide tube must be employed, as attempts to dispense with it by placing the oxide in the crucible itself gave too low results. The results obtained are practically identical with those from the ordinary combustion tube, as is shown by a number of tests which are given.

This crucible method is also adapted for the determination of carbonic anhydride and moisture in ores and limestones.

G. T. Dougherty † gives three methods for the determination of carbon in iron and steel. The graphite is determined by dissolving the metal in dilute nitric acid, weighing the residue on a filter-paper, and then burning off the graphite. Combined carbon is determined in a similar way in the residue from solution in an acid solution of the double chloride of potassium and copper, due allowance being made for the graphite, or by the colorimetric method.

---

* *American Manufacturer*, vol. lxv. pp. 135–158, 178, &c.

† *Iron Age*, May 11, 1899, pp. 30–31.

**Determination of Silicon.**—F. L. Crobaugh * states that the following mixture works well in the solution of steel for silicon determination, and rarely causes bumping:—Water, 1450 cubic centimetres; sulphuric acid, 1·84 specific gravity, 250; hydrochloric acid, 1·20 specific gravity, 100; and nitric acid, 1·42 specific gravity, 650 cubic centimetres. For the determination 0·47 gramme is dissolved in 15 cubic centimetres of the mixture on a hot plate, evaporation being gentle at first to allow complete solution. When the mass becomes dry and has given off sulphuric acid for two minutes, dehydration is complete. After cooling, the mass is extracted with hot hydrochloric acid of 1·20 specific gravity and filtered. A piece of filter-paper is used to wipe out the dish.

**Determination of Sulphur.**—O. Herting describes † various methods for the determination of sulphur in iron and steel. With regard to the volumetric method of J. Thill, who uses arsenious acid, the author observes that in recent years quite a number of methods have been proposed for the determination of sulphur in iron and steel, which depend on the liberation of the sulphur by an acid in the form of hydrogen sulphide. He refers to those of Meade and Wood All methods, however, in which it is attempted to determine the sulphur by liberation as hydrogen sulphide, give results that are too low, unless a combustion tube heated to redness is placed in front of the absorption tube. Rollet showed that when dilute hydrochloric acid acts on iron, only a portion of the sulphur escapes in the form of hydrogen sulphide, while the remainder is liberated in the form of an organic compound, which is not oxidisable by bromine-hydrochloric acid, hydrogen peroxide, &c., and Phillips ascertained that this substance has the composition $(CH_3)_2S$, methyl sulphide. He also showed that this compound when heated to redness in the presence of hydrogen and carbon dioxide is converted into sulphuretted hydrogen. Campredon and Schulte have both suggested methods which are not open to objection. The former passes the sulphuretted hydrogen into a zinc acetate solution acidulated with acetic acid, and then titrates the zinc sulphide with iodine solution, when zinc iodide is formed and sulphur liberated, while Schulte uses a cadmium acetate solution to absorb the $H_2S$, and then decomposes the cadmium sulphide by copper sulphate, and collects and determines the quantity of copper sulphide. The author considers that the method proposed by Blair for the determination of the total sulphur in iron is of a satisfactory character. This requires more time, but no complicated apparatus is required. It is as follows:—Dissolve 5 grammes of the iron in nitric acid, add from 2 to 5 grammes of potassium nitrate, and then evaporate in a platinum or good porcelain dish, and ignite. Then treat with water containing a little sodium carbonate, filter, and wash with water containing sodium carbonate. The filtrate is acidulated with hydrochloric acid, evaporated to dryness, taken up with water and hydrochloric acid, filtered, and precipitated boiling with barium chloride. This method is suitable when time is not a matter of urgent importance. For ordinary daily check analyses it is only necessary to perfect the Wiborgh colorimetric method in such a way as to ensure that the whole of the sulphur shall be absorbed as sulphuretted hydrogen by the cadmium. One of the author's assistants is engaged on this matter, and an account of his results will shortly be published. Schulte's analyses have shown that the percentage of organic sulphur varies in the case of white iron between 1·1 and 12·0 per cent. of the total sulphur, and from 7·2 to 52 per cent. in the case of spiegeleisen. In one sample of grey pig iron 5·4 per cent. of the total sulphur occurred as organic sulphur, and in another case this organic sulphur amounted to 51 per cent. of the total amount of sulphur present. In the case of the sulphur present in pyrites, the Lunge method gives satisfactory results. This consists in throwing down the iron by ammonia, and then precipitating the sulphuric acid by barium chloride. Heidenreich avoids the necessity for first precipitating the iron, by reducing the ferric salt by zinc before the precipitation of the sulphuric acid. No ferric sulphate falls with the barium sulphate in that case if the vessel in which the precipitation is effected is kept well covered and in the dark. Stannous chloride may be utilised in place of the zinc. Blast-furnace slags should be treated with bromo-hydrochloric acid, evapoporated to dryness, taken up with hydrochloric acid, the silicon filtered off, and the filtrate, which usually contains only small quantities of iron, precipitated with barium chloride. A volumetric determination of sulphur in blast-furnace slag can be effected in about 10 minutes by finely powdering the slag in an agate mortar, treating 0·5 gramme in an Erlenmeyer flask with 150 cubic centimetres of hot water, adding a few cubic centimetres of starch solution, and then an excess of standard iodine solution with 20 cubic centimetres of hydrochloric acid. After shaking for about a minute, the solution is titrated back with a standard solution of thiosulphate. The author referring to the methods for the determination of sulphur in coal, draws attention to the Hundeshagen modification of the Eschka method, which replaces the soda in the mixture MgO and $Na_2CO_3$, either wholly, or at least as to one half, by ignited potash.

---

* *Iron Trade Review*, July 20, 1899, pp. 16–18.

† *Chemiker Zeitung*, vol. xxiii. pp. 768–769.

Aulich * observes that in the precipitation of sulphuric acid from solutions which contain much ferric chloride the ignited barium sulphate always shows the presence of ferric oxide. It is assumed that ferric sulphate passes into the precipitate, and that this is decomposed when the precipitate is ignited. This can be avoided by boiling the freshly precipitated sulphate with concentrated hydrochloric acid after decanting off the supernatant solution, and then again adding some more barium chloride. It does not seem practicable to entirely avoid the precipitation of the iron salt. There are two main kinds of suggestion on this matter. One group of such proposals consists in first throwing down the iron by ammonia, and then precipitating the acid from the residual solution, or else adding the barium chloride immediately after the precipitation of the iron, and then dissolving the hydroxide with hydrochloric acid. Another method consists in causing the iron to combine with some organic acid, such as oxalic acid. An adequate quantity of ammonium oxalate must be added, and the solution boiled if success is to result. Finally there is the method in which the ferric salt is reduced to the ferrous condition before the precipitation of the sulphuric acid. Meineke has shown that metallic zinc is the best of such reducing agents. His method for the determination of sulphur in iron is as follows:—2½ grammes of the iron is treated with 1 gramme of potassium chlorate and 30 cubic centimetres of hydrochloric acid. The solution is rapidly effected without heating. After a further addition of chlorate and then elimination of chlorine by boiling, the ferric salt is reduced by zinc and the sulphuric acid in the solution precipitated by barium chloride. The author observes that practice alone will show whether this method is preferable for metallic iron to those in which the sulphur in the metal is converted into hydrogen sulphide. He considers it to be an improvement, however, in the case of ores, pyritic residues, &c., over the methods ordinarily adopted.

F. L. Crobaugh † uses the following method for the determination of sulphur. Five grammes of drillings are placed in a 16-ounce flask

---

* *Stahl und Eisen*, vol. xix. pp. 878–879.

† *Iron Trade Review*, July 6, 1899, pp. 12–13.

furnished with thistle funnel and outlet tubes, and 70 cubic centimetres of hydrochloric acid of 1·10 specific gravity are added in the cold. When evolution of gas becomes slow, the temperature is very gradually raised for about twenty minutes. The gas is passed into a solution consisting of 10 cubic centimetres of a cadmium solution, 125 of water, and 3 of starch solution. The cadmium solution consists of 20 grammes of cadmium chloride dissolved in 500 of water with 500 cubic centimetres of strong ammonia subsequently added. After the gas is dissolved, add an equal volume of cold water to the solution and sufficient hydrochloric acid to dissolve the yellow precipitate. Then titrate with iodine solution of a strength such that one cubic centimetre equals 0·005 per cent. sulphur until there is a distinct blue end reaction.

**Determination of Nickel.**—George W. Sargent* gives the following method for the determination of nickel in steel:—Dissolve 2 grammes of the steel in hydrochloric acid (1·1 specific gravity), add 1 cubic centimetre of strong nitric acid to oxidise the iron, and evaporate to hard dryness. Take up the residue in 20 cubic centimetres hydrochloric acid (1·1 specific gravity), evaporate to 10 cubic centimetres volume, and transfer the solution to a 250 cubic centimetre separatory funnel. Use warm hydrochloric acid (1·1 specific gravity) for washing the contents of the beaker into the funnel, taking care to keep the volume as small as possible. Cool the funnel and its contents under the tap, then introduce 40 cubic centimetres of ether free from alcohol, which has just been thoroughly shaken with 5 cubic centimetres of strong hydrochloric acid, and shake vigorously for ten minutes, keeping the temperature from rising by frequently holding the funnel under running water. Allow the funnel to stand a few minutes, draw off the lower aqueous layer containing the nickel, copper, manganese, and other chlorides not held by the ether, wash down the sides of the separatory funnel with hydrochloric acid (1·1 specific gravity), shake with the ether, and run the washings into the beaker with the chlorides of nickel, copper, &c. Two washings with 5 to 10 cubic centimetres of hydrochloric acid are sufficient to completely remove the nickel and other chlorides from the funnel. The ethereal solution containing the ferric chloride is run into a residue bottle, and later the ether recovered by distillation. Boil the liquid containing the nickel to completely expel the ether and add to the boiling solution, diluted to at least 200 cubic centimetres, an excess of ammonia and 10 to 20 drops of bromine water, to precipitate any iron or manganese. Filter, wash, redissolve in hydrochloric acid, reprecipitate with ammonia and bromine water, and filter. Combine the filtrates, boil, remove any precipitate, acidulate with hydrochloric acid, boil until the excess of bromine has been expelled, and precipitate the copper as sulphide. The filtrate from the copper sulphide, which contains nickel only, is evaporated to a volume of 100 cubic centimetres, cooled, and 1 centimetre excess of ammonia added. Now introduce into the nickel solution, which is best contained in an Erlenmeyer flask, 5 cubic centimetres of silver nitrate solution (one-half gramme silver nitrate in a litre of water), and the same amount of a 2 per cent. solution of potassium iodide. Run into the opalescent solution, which should have a temperature slightly lower than that of the hand, standard potassium cyanide (1 cubic centimetre equal to about 0·001 gramme of nickel) until the liquid becomes clear and bright. This titration is best made with a black background, when the end-reaction becomes very sharp and decided after a little practice, half a drop only being sufficient to discharge the opalescence. Ferro-nickel is dissolved in aqua regia.

---

* *Journal of the American Chemical Society*, vol. xxi.

According to Giovanni Giorgis,* Gibb's method of estimating nickel, namely, precipitating with an alcoholic solution of oxalic acid of known strength, and by means of permanganate determining either the oxalic acid left in the filtrate or that contained in the precipitate, is inaccurate. This is due, firstly, to the partial solubility of the nickel oxalate, and secondly, to the fact that the removal of the alcohol from the liquid cannot be completely effected without decomposing some of the oxalic acid. To remove these objections, the author has devised an improved process, which consists in using as precipitant an oxalic acid solution of either barium or strontium oxalate of known strength. No addition of alcohol is necessary, for on boiling the liquid the nickel is thrown down quantitatively as oxalate. The oxalic acid in the filtrate may then be estimated by titrating an aliquot part with permanganate, or that in the precipitate by treating it with a little sodium carbonate, acidifying with sulphuric acid and titrating with permanganate. Test analyses of nickel sulphate solutions and of nickeliferous steels show that the method gives good results.

---

* *Gazetta Chimica Italiana*, vol. xxix. pp. 72-80.

**Determination of Titanium and Vanadium.**—F. J. Pope* gives details of a number of experiments on the determination of titanium and vanadium in titaniferous iron ores. The volumetric method of Wells and Mitchell obviates most of the difficulties, but the vanadium causes an error in the estimation of titanium. Blair's method gives good results for titanium, but a number of precautions are necessary for its satisfactory working, and these are dealt with at some length. Some vanadium also accompanies the titanium, but may be removed in the way described by fusion with sodium carbonate, which gives a soluble vanadate and an insoluble titanate of sodium. Vanadium is determined by fusion with sodium nitrate, any manganese reduced by alcohol, and barium used to precipitate the vanadate. The precipitate is dissolved in sulphuric acid, and converted into ammonium metavanadate, and then into vanadic oxide. Traces of chromium and phosphorus are sometimes present, so that the vanadium has to be determined by titration with potassium permanganate.

## II.—*ANALYSIS OF IRON ORE.*

**Determination of Iron.**—J. T. Norton † discusses the estimation of iron in the ferric state by reduction with sodium thiosulphate and titration with iodine, and finds it to be accurate in certain conditions. The method advocated consists in dissolving 0·2 gramme in hydrochloric acid, evaporating to a pasty mass, diluting to 800 cubic centimetres with freshly-boiled water, adding a drop of potassium sulphocyanide and 50 cubic centimetres of $\frac{n}{10}$ sodium thiosulphate. When the solution is colourless, the excess of thiosulphate is determined by $\frac{n}{10}$ iodine and starch.

K. Schröder ‡ discusses the use of potassium ferrocyanide in the volumetric determination of iron. It is not an easy matter, he shows, to determine the percentage of water contained in the salt. When he endeavoured to do this by heating the salt in an open crucible to 100° C., the dried ferrocyanide proved so hygroscopic that it was only possible to obtain an approximately correct weight by very rapid weighing, and even then the percentage of water so ascertained proved to be more than 0·1 per cent. lower than the theoretical percentage. Potassium ferrocyanide the author shows to possess various advantages over ferro-ammonium sulphate. This latter salt is often impure, as Meineke has shown. Other salts are also referred to, but the author considers potassium ferrocyanide to be preferable for standardising purposes, and he shows how it may best be utilised. To determine the percentage of iron in the salt the author decomposes it completely with sulphuric acid, takes up with water and hydrochloric acid, and then precipitates almost at boiling temperature with ammonia. To eliminate any potassium sulphate from the precipitate, it is re-dissolved in hydrochloric acid, and again precipitated. After ignition and weighing, the oxide is fused with potassium hydrogen sulphate of known silica contents, for the purpose of determining the percentage of silica contained in the oxide. The author also describes how the percentage of carbon contained in the salt may best be determined.

---

* *Transactions of the American Institute of Mining Engineers*, October 1899.

† *American Journal of Science*, vol. viii. pp. 25–30.

‡ *Chemiker Zeitung*, vol. xxiii. pp. 533–534, 540–541.

H. Verwer and Friedrich Groll * do not agree with the conclusions of Avery and Dales, that the use of ammonium oxalate in the electrolysis of iron salts causes the separation of carbon at the cathode, and further, leaves some of the iron unchanged in the solution. They have carried out a number of experiments, and find that in no case is the percentage of iron too high, and that the solution after the electrolysis does not contain unchanged iron salt.

**Determination of Sulphuric Acid.**—According to C. Meineke,† to obviate the well-known error in the estimation of sulphuric acid in solutions containing much ferric chloride, the latter is reduced by zinc. To apply the method to pyrites residues, 2·5 grammes of the substance is dissolved in hydrochloric acid and potassium chlorate; the chlorine is expelled, zinc in the form of granules or coarse filings is added, and when reduction is complete the solution is filtered, and is then ready for precipitation with barium chloride. A pure white precipitate is obtained, the weight of which agrees closely with that obtained by Schröder's more tedious, but admittedly accurate, method of fusion with sodium carbonate and potassium chlorate. The same process serves for the estimation of sulphur in pig iron, and the results are identical with those yielded by the author's cupric chloride method.

---

* *Berichte*, vol. xxxii. pp. 806–809; *Journal of the Chemical Society*, vol. lxxvi. p. 386.

† *Zeitschrift für Analytische Chemie*, vol. xxxviii. pp. 209–217.

**Determination of Phosphoric Acid in Basic Slag.** — C. Aschman * discusses the determination of the total phosphoric acid in basic slag. He observes that it is difficult to understand the continued use of boiling concentrated acids to dissolve basic slag, when a 2 per cent. solution of hydrochloric or nitric acid will bring all the phosphoric acid into complete solution in a rotating apparatus within about half-an-hour, and that without any heating whatever. Silica is, however, usually subsequently precipitated with the phosphoric acid, and to avoid these difficulties the author has devised a method in which he uses as the solvent nitro-sulphuric acid. The phosphoric acid can then be precipitated direct with magnesia mixture, except in a few cases when the use of molybdate solution becomes necessary. His method is as follows:—Prepare a solution consisting of 420 grammes of pure nitric acid of 1·2 specific gravity, and 50 grammes of concentrated sulphuric acid, and dilute with water to 10 litres. Also prepare a citric acid solution consisting of 500 grammes of citric acid dissolved in water and diluted to one litre. The magnesia mixture to be used is obtained by dissolving 110 grammes of pure crystallised magnesium chloride and 140 grammes of ammonium chloride in 700 cubic centimetres of 8 per cent. ammonia solution, and 1300 cubic centimetres of water. A suitable molybdate solution can be made by dissolving 150 grammes of ammonium molybdate in some water in a litre flask. To the solution 400 grammes of ammonium nitrate is added, the flask filled up to the mark with water, and the solution subsequently poured into a litre of nitric acid of 1·19 specific gravity. This mixture is allowed to stand for twenty-four hours at 35° C. and is then filtered.

Five grammes of the finely ground slag is placed in a shaking flask of one-half litre capacity. This is then filled to the mark with the nitro-sulphuric acid, stoppered with a soft india-rubber stopper, and shaken for half-an-hour in a Wagner rotating apparatus, making some 40 or 45 revolutions per minute. It is then filtered and allowed to stand over-night, or for about twelve hours, during which period most of the calcium sulphate settles out. To 50 cubic centimetres of the filtrate 10 cubic centimetres of the nitric acid solution is added, and the whole neutralised with ammonia until slightly alkaline. Fifty cubic centimetres of water is then added. After twenty minutes the solution must be perfectly clear. The phosphoric acid can then be precipitated by the addition of 20 cubic centimetres of magnesia mixture, and stirring for half-an-hour; after one or two hours the solution can be filtered. The subsequent operations are of the usual kind. If after twenty minutes the ammonium nitrate should precipitate flocculent silica, the phosphoric acid must first be precipitated in the ordinary manner by molybdate. The nitro-sulphuric acid solution dissolves in half-an-hour's rotation about 90 per cent. of the basic slag. The insoluble portion consists of metallic iron, silica, coal-dust, &c.

---

* *Chemiker Zeitung*, vol. xxiii. p. 435.

## III.—*FUEL ANALYSIS.*

**Analysis of Coal.**—Maurice * describes some rapid gravimetric methods that he uses for determining approximately the amount of moisture and the amount of shale, and even of ash in washed coal used for coking and other purposes. For determining the moisture, a definite weight of the wet coal is shaken up with twice its weight of a calcium chloride solution of 1·40 specific gravity, the solution is filtered off, and its specific gravity determined. An easy calculation or a table shows the amount of water taken up. To determine the shale and coal the mixed material is placed in a liquid of such a specific gravity that the one sinks and the other rises. A convenient form of apparatus for carrying out the separation is described, and the mathematical side of the question is fully discussed.

**Determination of Sulphur in Coal.**—U. Anthony and E. Lucchesi † use the following method for the determination of sulphur in coal. One gramme of the sample is mixed with a mixture of manganese dioxide 4 grammes, potassium permanganate 1 gramme, and dry sodium carbonate 2 grammes, in a platinum crucible, heated gently at first, and then until the bottom is red-hot. The cooled mass is then transferred to a beaker containing 40 to 50 cubic centimetres of water acidulated with nitric acid and heated. After filtration the sulphate is precipitated as the barium salt.

**Determination of Sulphur in Roumanian Petroleum.**—According to G. Filiti, ‡ the estimation of the sulphur in petroleum by the ordinary methods of oxidation is unsatisfactory, and attended by various sources of error. Excellent results are obtained by combustion with oxygen in the calorimetric bomb in presence of a little water. Employing this method, six specimens of petroleum from Campina were found to contain 0·202–0·245 per cent. of sulphur, whilst six specimens of Bustenari petroleum yielded 0·118–0·193 per cent.

---

* *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1899, pp. 144–165.

† *Gazetta Chimica Italiana*, vol. xxix. pp. 181–184.

‡ *Bulletin de la Société Chimique de Paris*, vol. xxi. pp. 338–341.

Marcellin Berthelot * points out that, in conjunction with André and Matignon, he had already established the use of the calorimetric bomb for the analysis of sulphur compounds.

## IV.—*GAS ANALYSIS.*

**Determination of Oxygen.**—K. Molterski † describes and illustrates an apparatus for the determination of oxygen in gases, which is in use in the Witkowitz coalfield in connection with fire-damp analysis. In this apparatus the oxygen is absorbed by phosphorus. Best results are obtained at a temperature of 20° C., while at 15° C. it is not possible to completely absorb the oxygen. With one "filling" of phosphorus it is possible to make many hundred analyses.

* *Bulletin de la Société Chimique de Paris*, vol. xxi. p. 513; *Journal of the Chemical Society*, vol. lxxvi. pp. 574–575.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 164; one illustration.

## II.—*AUSTRALASIA.*

**Mineral Statistics of New South Wales.**—The output of coal for 1898 again shows[*] a substantial increase over that of the preceding year. The output for 1897 was the largest recorded since the opening of the first coalfield in 1829, but that of 1898 exceeded it by 322,659 tons, the total output for 1898 being 4,706,251 tons, as against 4,383,591 tons in 1897. There was an increase in the home consumption of coal of 227,487 tons, and an increase in the inter-colonial exports of 130,080 tons, but the foreign exports fell off to a slight extent, the decrease being 34,907 tons, representing about 3 per cent. on the volume of foreign exports for 1897. The production of coke in 1898 was 322,028 tons.

**Mineral Statistics of Victoria.**—According to official returns[†] the output of coal in Victoria during 1898 amounted to 242,859 tons, valued at the pit's mouth at £103,099. This return shows an increase of 6582 tons over that for 1897, but the value decreased from 9s. 7d. to 8s. 6d. per ton. Of the output for 1898 the Outtrim Howitt Company raised 139,781 tons, the Jumbunna Company 71,499 tons, and the Coal Creek Proprietary Company 30,554 tons. The Great Morwell Company raised 2869 tons of brown coal, of a value of £767.

## III.—*AUSTRIA-HUNGARY.*

**Mineral Statistics.**—The Austrian official mineral statistics for 1898 have been published.[‡] The principal items are as follows:—

| | Metric Tons. |
|---|---|
| Coal | 10,947,521 |
| Brown coal | 21,083,360 |
| Iron ore | 1,733,649 |
| Pig iron | 957,836 |

**Accidents in Mines.**—In the year 1897 there were in the Austrian mines 168 fatal accidents and 820 severe ones.[§] In addition one woman was killed and ten severely injured. In smelting works there were two fatal and twenty-eight severe accidents. The following table shows the ratio borne by the accidents to the quantity of mineral raised:—

---

[*] *Annual Report of the Department of Mines*, Sydney, 1899, p. 25.

[†] *Annual Report of the Secretary of Mines*, Melbourne, 1899.

[‡] *Statistiches Jahrbuch des k.k. Ackerbau-ministeriums*, 1899, Part II.

[§] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 322–323.

| | For each Fatal Accident. | | For each Accident of any Kind. | |
|---|---|---|---|---|
| | Metric Tons of Mineral Raised. | | Metric Tons of Mineral Raised. | |
| | In 1897. | In 1896. | In 1897. | In 1896. |
| Coal . . . . | 190,778 | 147,751 | 29,309 | 31,328 |
| Brown coal . . | 217,639 | 190,733 | 39,724 | 34,968 |
| Iron ore . . . | 268,979 | 181,077 | 40,347 | 49,952 |

Details are given as to the places in which the accidents took place, and the causes of these accidents are also enumerated. The number of workpeople employed at the mines and smelting works of Austria in 1897 was as follows:—Men, 120,244; women, 6660; boys and girls, 6126; and children, 13. This is an increase of about 5000 as compared with the numbers employed in 1896.

**Iron Trade Exports and Imports.**—M. Caspaar* states that the iron trade imports and exports of Austria-Hungary in 1898 were as follows in metric tons:—

| | Imports. | | Exports. | |
|---|---|---|---|---|
| | 1897. | 1898. | 1897. | 1898. |
| Brown coal . . | 19,609 | 19,393 | 8,108,975 | 8,351,935 |
| Coal . . . . | 5,121,475 | 5,396,740 | 701,919 | 840,505 |
| Coke . . . . | 533,463 | 606,783 | 145,056 | 194,322 |
| Manganese ore . . | 8,018 | 5,396 | 622 | 1,961 |
| Iron ore . . . | 134,778 | 178,235 | 247,856 | 302,317 |
| Iron and iron wares . | 211,934 | 228,821 | 50,535 | 61,790 |

Details are given as to the various items forming the "iron and iron wares" shown in the table. The chief item is foundry pig iron, of which, in 1898, 118,574 tons was imported and only 1231 tons exported. Of machines and other apparatus 42,353 tons was imported in 1898 and 12,909 tons exported. The tables show also the exports and imports of the various countries with which Austria-Hungary has trading relations.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 193–196 and 210–212.

It will be seen that in 1898 there was a considerable increase in the imports of coal and coke. Of the brown coal exported 99 per cent. went to Germany, and also 68 per cent. of the coal. The coke went chiefly to Russia. There was a considerable increase in 1898 as compared with the previous year in both the imports and exports of iron ore, and it is observed that while the imports from Spain and Sweden showed a diminution, there was for the first time an importation of iron ore from Algeria, and the imports from Greece showed a considerable increase. The ore exported was nearly all sent to Germany. The imports of iron and iron wares in 1898 was 7·9 per cent. in excess of the similar imports in 1897. Of the total imported, 35 per cent. was from the United Kingdom, 42 per cent. from Germany, and 14 per cent. from the United States. The total value of the imports of iron and iron wares was 19,178,360 Austrian florins in 1897 and 20,017,256 florins (say £1,668,105) in 1898. The consumption of pig iron in Austria in 1898 was 1,464,776 tons.

**Ironworks in Bohemia.**—A congress of mining engineers was held in August at Teplitz, the centre of the Bohemian brown coal industry. It was attended by four hundred of the leading Austrian mining engineers, and by a few representatives from other countries, Great Britain being represented by H. Bauerman, Bennett H. Brough, and D. A. Louis. An attractive programme of papers, excursions, and social functions was arranged. Among the excursions connected with the congress, the visit to the Rudolf plate-rolling mills at Teplitz, the Teplitz rolling-mills at Zuckmantel, and the Teplitz shovel and tool works gave an excellent idea of the recent remarkable development of the Bohemian iron trade. The first-named works, which are the property of a joint-stock company formed in 1884 with a capital of 400,000 florins, since increased to 2,600,000 florins, manufacture all kinds of black-plates from 0·15 to 4 millimetres thick, as much as 5 feet wide and up to 26 feet in length, also galvanised plates, stove-plates, mild steel plates, crucible steel plates, and corrugated plates of all kinds. As the specialty of the works there are produced plates 100 feet to 130 feet in length, 24 inches in breadth, and 0·08 inch thick, which are divided into two strips, each a foot in width. These are exported to Australia, and there converted into spiral pipes for purposes of water supply. The production of the Rudolf Works in the financial year 1898–99 was 16,000 tons of plates. The works afford employment for 750 men.

The second works, the Teplitz rolling-mills, were begun in 1872 for the production of Bessemer rails, as well as of puddled iron rails. The Bessemer works were equipped with two converters and three open-hearth furnaces. Brown coal was the only fuel available, and as the phosphoric pig iron of Bohemia could not then be used, all the pig iron required had to be obtained from Styria, Sweden, Germany, and England. In the building of the works, Paul Kupelwieser was aided by a young man, Carl Wittgenstein, who has since played so important a part in the development of the Austrian iron trade. In 1876 P. Kupelwieser was appointed general manager of Rothschild's ironworks at Witkowitz, and Carl Wittgenstein succeeded him at Teplitz. Owing to the manufacture not being confined to rails, the works rapidly developed, and in 1883 the basic Bessemer process was adopted. At the same time Wittgenstein acquired mines and blast-furnaces, so that the Teplitz works became independent of foreign supplies. In 1886 an amalgamation was effected with the Prague Ironworks Company, the keenest competitor with the Teplitz rolling-mills. The production of the Teplitz rolling-mills is now about 50,000 tons of rolled steel annually, consisting chiefly of sleepers, boiler-plates, rails, and unfinished products for the manufacture of Mannesmann tubes. The number of workmen employed amounts to 1200.

**Brown Coal in Bohemia.**—The statistics published by the Aussig-Teplitz Railway show the quantity of brown coal produced in the Bohemian brown coal district in 1898 to have been as follows:*—

| District. | Production. | Workpeople. |
|---|---|---|
| | Metric Tons. | |
| Elbogen—Falkenau . . . . | 2,205,953 | 5,625 |
| Teplitz—Brüx—Komotau . . | 15,044,563 | 25,212 |

The total production shows an increase of the output of 378,852 tons as compared with the production in the previous year. Of the total output, 53 per cent. was used in the country and 47 per cent. exported, a large proportion of which was sent to Germany. The production more than doubled between the years 1880 and 1890, and in 1898 was about 50 per cent. higher than it was in 1890.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 406.

**Production of Petroleum.**—Altogether there were in Austria in 1897 as many as 360 undertakings for the winning of petroleum.* Of these, 245 were in active operation, 128 of which were in the Jaslo mining district, and 82 in the Drohobycz mining district. The production of petroleum amounted to 275,204 metric tons, of the approximate value of £490,000, this being an increase of 4·90 per cent. in quantity and 13·26 per cent. in value as compared with the figures for the previous year. The workpeople employed number 2659, all of whom were men, with the exception of twelve women and children. This is an increase of 1015 as compared with the previous year. Details are given as to the shafts and boreholes in operation.

**Production of Ozokerite.**—In 1897 there were in Austria 65 mining undertakings for the winning of ozokerite. Of these, 47 were in active operation, 33 being in the Drohobycz mining district. The workpeople employed numbered 6084 men and 323 women. The production amounted to 6882 metric tons, valued at about £152,000, this being, as compared with the figures for 1896, an increase in the output of 4·70 per cent., and in value of 5·54 per cent.†

**Hungarian Mineral Statistics.**—The official mineral statistics of Hungary for the year 1897 have been published.‡ The production included :—

| | Metric Tons. |
|---|---|
| Brown coal | 3,876,223 |
| Coal | 1,132,624 |
| Patent fuel | 31,179 |
| Coke | 15,550 |
| Pig iron | 384,345 |
| Iron ore exported | 391,662 |

**Mineral Statistics of Bosnia and Herzegovina.**—Official statistics for the year 1898 § show the production to have included :—

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 333.

† *Ibid.*, vol. xlvii. p. 350.

‡ *Montan Zeitung*, vol. vi. p. 243.

§ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 297–299.

| | Metric Tons. |
|---|---|
| **Brown coal** | 271,184 |
| **Iron ore** | 58,533 |
| **Chrome ore** | 458 |
| **Manganese ore** | 5,319 |

These totals were all in excess of those for the preceding year. The production of brown coal in 1898 exceeded that in 1897 by 41,540 tons, and the production of iron ore showed a similar excess of 21,438 tons.

The production of the smelting works included 15,366 tons of pig iron, 942 tons of castings, 8511 tons of rolled iron, and 8669 tons of open-hearth ingots. The workpeople employed at the collieries numbered 777; at the iron ore mines, 154; and at the ironworks, 731. The total number of workpeople employed at all the mines and smelting works was 3910, an increase of 410, or 11·7 per cent., as compared with the total for the previous year. There were four fatal and eleven severe accidents to workpeople during the year.

With regard to the improvements undertaken at the various mines and works during 1898, it is stated that at the Zenica colliery the washing plant was further improved, and that at the Vareš ironworks a new blast-furnace was commenced. This is to have a daily capacity of 80 tons. The pipe stoves are also being replaced by four Cowper stoves. Four calciners were also erected, and the railway connection between the mines and the smelting works further perfected.

F. Poech * gives the following statistics showing the progress made in the coal industry of Bosnia during recent years:—

| Year. | Production. Metric Tons. | Workpeople Employed. |
|---|---|---|
| 1880 | 500 | 16 |
| 1885 | 23,009 | 143 |
| 1890 | 59,342 | 215 |
| 1895 | 195,442 | 750 |
| 1898 | 268,700 | 830 |

The value of the output in 1898 was 567,710 gulden, or about £47,300.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 369.

## IV.—*BELGIUM.*

**Mineral Statistics.**—The report published each year by E. Harzé * on the Belgian mineral statistics contains a mass of information regarding the coal and iron trades. The latest report shows that in 1898 the Belgian output of coal was 22,088,335 tons, valued on an average at 11 francs a ton. The average thickness of the seams worked was 26 inches, and the average depth of the workings was 1400 feet. The coke made amounted to 2,161,162 tons, valued at 18·75 francs a ton. There were 4028 coke-ovens in operation, and 2519 workmen were employed. Of briquettes, 1,351,884 tons, valued at 13·39 francs a ton, were made at 37 works with 69 presses and 1191 workmen. The iron trade production comprised 979,755 tons of pig iron from 36 blast-furnaces, 485,040 tons of wrought iron, and 567,728 tons of finished steel.

The *Statistical Year Book* issued by the Minister of the Interior † contains the mineral statistics for 1897. There were in that year in operation in Belgium 1523 quarries, employing 32,601 men, and raising mineral worth 48,904,276 francs. The production of the metal mines included :—

| | Quantity. | Value. |
|---|---|---|
| | Tons. | Francs. |
| Iron ore . . | 240,774 | 1,264,510 |
| Manganese ore | 28,372 | 342,700 |

There were 1934 miners employed, the mean daily wage being 2·68 francs. Of coal 21,492,446 tons were raised, 120,382 workpeople being employed. The mean annual wage was 1006 francs, and the average output per person employed 179 tons.

**Blast-Furnaces.**—At July 1, 1899, there existed in Belgium 40 blast-furnaces.‡ Of these, 36 were in blast, 21 of which were making pig iron for steel manufacture.

---

* *Moniteur des Intérêts Matériels*, vol. xlix. pp. 2833–2834.

† *Annuaire Statistique de la Belgique*, vol. xxix. 1899, p. 310.

‡ *Echo des Mines et de la Métallurgie*, vol. xxvi. p. 5624.

The production of pig iron in Belgium during the first half of 1899 amounted to 596,770 tons, as compared with 503,945 tons in the first half of 1898. This will be seen from the following table:—

| | Production. | |
|---|---|---|
| | First Half of 1899. | First Half of 1898. |
| | Metric Tons. | Metric Tons. |
| Forge pig iron | 162,485 | 188,185 |
| Foundry pig iron | 51,535 | 33,495 |
| Pig iron for steel-making | 382,750 | 281,265 |
| Totals | 596,770 | 502,945 |

Foundry pig iron was only made in the Liége district, where four furnaces were making it. Of the active blast-furnaces, 16 were in the Charleroi district, 14 in that of Liége, and 6 in Luxembourg.

**Mines in Belgium.**—Théo Spée* gives a tabulated statement of the mining concessions granted in Belgium from 1794 to July 1, 1899. The concessions are given in alphabetical order, and full particulars of their nature and extent are appended. The tables cover no less than 130 pages.

## V.—*CANADA.*

**Mineral Statistics.**—The mineral statistics of the Dominion of Canada for 1898 † comprise:—

| | Metric Tons. |
|---|---|
| Iron ore | 52,763 |
| Chrome iron ore | 1,833 |
| Coal | 3,785,408 |
| Coke | 65,721 |
| Fireclay | 1,969 |
| Limestone for flux | 30,766 |
| Manganese ore | 45 |
| Nickel ore | 2,502 |
| Moulding sand | 9,591 |

The production of crude petroleum was 700,790 barrels.

The mineral production of Nova Scotia ‡ in 1898 comprised 2,317,957 metric tons of coal, 42,672 metric tons of coke, 31,547 metric tons of iron ore.

---

* *Annales des Mines de Belgique*, vol. iv. pp. 533–661.

† *The Mineral Industry*, New York, vol. vii. 1899, p. 818.

‡ *Annual Report of the Department of Mines of Nova Scotia.*

The mineral production of Ontario* in 1898 included 25,556,591 gallons of crude petroleum.

The annual report of the Minister of Mines for British Columbia† gives the production of coal in 1898 at 1,135,865 tons, and that of coke at 35,000 tons.

**Iron-Smelting in Canada.**—James Douglas‡ has published a paper read before the Canadian Mining Institute on Swedish iron metallurgy and its application to Canada, in which he compares the similar conditions of Canada and Sweden, and shows how the former country may learn from the latter.

## VI.—*FRANCE.*

**Iron Trade Statistics.**—According to the returns published by the Comité des Forges,§ the French iron trade imports and exports during the first half of 1899 comprised :—

| | Imports. | Exports. |
|---|---|---|
| | Metric Tons. | Metric Tons. |
| Coke . . | 688,130 | 28,810 |
| Iron ore . | 952,239 | 140,536 |
| Pig iron . | 38,064 | 82,807 |
| Wrought iron | 14,035 | 29,527 |
| Steel . . | 5,167 | 18,602 |

**Blast-Furnaces.**—On July 1, 1899, there were in France 136 blast-furnaces. Of these, 101 were in blast. They were divided as follows among the different districts :—

| District. | Blast-Furnaces. | | |
|---|---|---|---|
| | In Blast. | Out of Blast. | Total. |
| East . . . . . . . . . . | 62 | 14 | 76 |
| North . . . . . . . . . . | 10 | 8 | 18 |
| Centre and South . . . . . . | 29 | 13 | 42 |

---

* *Annual Report of the Bureau of Mines of Ontario.* Toronto, 1899.

† *Canadian Mining Review,* vol. xviii. p. 169.

‡ *Ibid.,* vol. xviii. p. 43.

§ *Bulletin,* No. 1481.

The total active furnaces were able to produce per day 7483 tons of pig iron. Foundry pig iron was not being made in the Northern district.[*]

**Algerian Iron Ore.**—According to an article[†] on the mining industry of Algeria, the exports of iron ores from the districts of Oran and Bona are very considerable. In the latter region, whence 115,844 tons were exported in 1898, the ore is obtained from the mines of Ain Mokra, belonging to the Mokta-el-Hadid Company. The ore is of good quality, but the cost of haulage and transport prevents it from competing with Bilbao ore. The ore from Bona is exported to Germany, England, and France. In Oran the conditions are more favourable, the exports last year having amounted to 366,507 tons, as compared with 343,657 tons in 1897. A couple of years ago only the mine of Benisaf exported ore. Since then, however, the mines of Rar-el-Maden and Kristel have been started. The Algerian mining industry is capable of great development. Mining is still very costly and transport difficult. Want of loading wharves is also a difficulty. The construction of light railways will have to be undertaken before the valuable deposits in the interior can be worked.

## VII.—*GERMANY.*

**Imports and Exports.**—The imports and exports of Germany during the first half of 1899 included : [‡]—

| | Imports. | | Exports. | |
|---|---|---|---|---|
| | First Half of 1898. | First Half of 1899. | First Half of 1898. | First Half of 1899. |
| | Metric Tons. | Metric Tons. | Metric Tons. | Metric Tons. |
| Iron ores . . . | 1,477,553 | 1,761,567 | 1,476,015 | 1,578,144 |
| Slags, slag wool, &c. . | 361,397 | 384,801 | 13,388 | 13,432 |
| Basic slag, ground . | 39,142 | 33,270 | 52,412 | 51,675 |
| Pig iron . . . | 163,893 | 242,747 | 91,363 | 94,380 |
| Scrap . . . . | 8,720 | 34,274 | 47,373 | 28,234 |
| Weld iron, bars, &c. . | 11,087 | 13,377 | 138,772 | 105,970 |
| Rails . . . . . | 180 | 181 | 61,297 | 56,205 |
| Railway sleepers, &c. | 43 | 156 | 17,905 | 15,772 |
| Wrought iron sheets and plates | 2,862 | 3,524 | 79,343 | 82,326 |
| Tin-plate . . . | 4,250 | 12,172 | 69 | 55 |
| Wire . . . . . | 3,590 | 4,233 | 99,655 | 83,212 |
| Total of all kinds of iron and iron wares | 266,336 | 415,083 | 937,736 | 892,806 |

---

[*] *Echo des Mines et de la Métallurgie*, vol. xxvi. p. 5592.

[†] *Deutsche Volkswirthschaftliches Correspondenz*, August 29, 1899.

[‡] *Stahl und Eisen*, vol. xix. p. 791.

Included in the above general total were among the exports during the first half of 1899, 89,742 tons of iron wares in the rough, 23,620 tons of wire rod, 11,192 tons of finished castings, and 96,743 tons of machinery, consisting chiefly of iron, both cast and wrought.

In his opening address at the April meeting of the Verein Deutscher Eisenhüttenleute, C. Lueg,* in dealing with the question of transport facilities in Germany, gives the following figures as representing the imports of iron ore into Germany in the years mentioned:—

| | Metric Tons. |
|---|---|
| 1893 | 1,573,202 |
| 1894 | 2,093,007 |
| 1895 | 2,017,136 |
| 1896 | 2,586,706 |
| 1897 | 3,185,643 |
| 1898 | 3,516,577 |

In 1898 the imports of Swedish ores alone amounted to 1,446,842 tons. It will be seen that during the past six years the imports of iron ore have more than doubled. The necessity for endeavouring to reduce the cost of transport from the mine to the furnace is particularly referred to.

**Mineral Statistics of Prussia.**—According to the official statistics, the mineral production of Prussia in 1898 included: †—

| | Metric Tons. |
|---|---|
| Coal | 89,573,528 |
| Brown coal | 26,035,814 |
| Asphalt | 12,822 |
| Petroleum | 2,545 |
| Iron ore | 4,020,809 |
| Manganese ore | 42,231 |

**Mineral Statistics of Upper Silesia.**—In the year 1898, at 54 active colliery undertakings in Upper Silesia there were employed 55,797 men and 3619 women.‡ The number of workpeople was 2·7 per cent. greater than it was in 1897, but the output increased by 9·4 per cent. The output has almost doubled in the last twelve years, having risen from 13,088,246 tons to 25,502,199 tons. The yield per workman was 378·7 tons.

There were in 1898 in Upper Silesia 42 active iron ore mines.

---

* *Stahl und Eisen*, vol. xix. p. 405.

† *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlvii. pp. 2–28.

‡ *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 331–332, 348–350.

The workpeople employed numbered 1748 men and 1138 women. The ore produced was 418,555 tons. At 11 ironworks in 1898 there were 37 coke blast-furnaces, 32 of which were active. The workpeople employed numbered 4018. The furnaces consumed 1,117,897 tons of ore, 8060 tons of scrap, 448,571 tons of limestone and dolomite, 381,360 tons of slag and cinder, and 919,014 tons of coal and coke. This yielded 292,896 tons of forge pig iron, 189,364 tons of basic pig iron, 52,497 tons of foundry pig iron, and 46,672 tons of Bessemer pig iron. As secondary products there were obtained from this blast-furnace practice 383 tons of argentiferous lead; 706 tons of furnace accretions; 5730 tons of zinc dust, and 118,156 tons of manufactured slag. The home consumption of pig iron amounted to 683,737 tons. Only 1 charcoal ironworks was in operation. At 25 foundries, 46 cupolas, 8 open-hearths, and 11 other furnaces were in use. The castings made amounted to 75,959 tons, 2829 workpeople being employed. Weld and ingot iron were made at 20 works. These possessed 278 puddling furnaces and 232 other furnaces of various kinds used in making weld iron, together with 60 steam-hammers and 33 presses; while for the manufacture of ingot metal there were in use 2 acid and 6 basic Bessemer converters, 20 open-hearths, 8 cupolas, 2 crucible steel furnaces, 69 other furnaces, 2 dolomite calciners, 15 steam-hammers, and 4 presses. The trains of rolls in use numbered 89. Altogether 18,550 workpeople were employed. From 1,023,139 tons of iron and iron ores and 1,134,183 tons of coal, 743,326 tons of metal were produced. The production of ingot metal semi-manufactures was 555,505 tons.

At 14 works 4086 workpeople were engaged in the coke industry. The production of lump coke amounted to 1,166,034 tons; of small coke to 87,714 tons, and of coke fines to 94,072 tons. Of by-products 107,091 tons was produced. The total quantities raised or produced were as follows:—

| | Production. | Total Value. | Workpeople. | Wages. |
|---|---|---|---|---|
| | Metric Tons. | £. | | £. |
| Coal and ores of all kinds | 23,479,776 | 7,325,610 * | 73,814 | 2,911,953 |
| Iron and steel . . | 1,690,049 | 7,050,120 | 31,654 | 1,287,224 |
| Coke . . . . | 1,454,911 | 932,092 | 4,086 | 144,840 |

**Mineral Statistics of Bavaria.**—There were produced in Bavaria in 1898:*—

| | Production. | Active Mines. |
|---|---|---|
| | Metric Tons. | |
| Coal | 964,611 | 17 |
| Brown coal | 38,663 | 10 |
| Iron ore | 171,987 | 45 |
| Graphite | 4,593 | ... |
| Petroleum | 12 | ... |
| Fireclay | 282,994 | ... |

The production of iron and steel was as follows:—

| | Metric Tons. | Active Works. |
|---|---|---|
| Pig iron and castings | 168,467 | 82 |
| Bar iron | 58,341 | 11 |
| Iron wire | 323 | ... |
| Steel | 120,623 | 3 |

Details are also given as to the production of other minerals and metallurgical products. The workpeople employed in the various branches of mining included:—

| | |
|---|---|
| Collieries | 6080 |
| Brown coal mines | 243 |
| Iron ore mines | 738 |
| Iron and steel works | 9035 |

**Krupp's Works.**—Some interesting particulars regarding Krupp's works at Essen have been published.† On January 1, 1899, there were employed 41,750 persons, including 3210 officials. The cast steel works at Essen alone employed 25,133 persons, the Gruson works 3548, the Germania wharf at Kiel 2726, and the works at Meppen 10,343. The consumption of coal and coke at the cast steel works at Essen amounted last year to 786,415 tons, and at all works of the firm to 1,199,610 tons, or about 4000 tons daily.

**Coal and Coke.**—According to Jencke,‡ the average prices of the different kinds of coal, coke, and briquettes have been as

---

[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 320.
[†] *Der Gnom*, vol. ii. pp. 638–639.
[‡] *Stahl und Eisen*, vol. xix. p. 696.

follows in Germany in the years stated, the price being stated in shillings:—

| | 1888. | 1890. | 1892. | 1895. | 1898. |
|---|---|---|---|---|---|
| Household coal . | 6·32 | 12·36 | 9·75 | 8·33 | 8·84 |
| Caking coal . | 6·04 | 10·72 | 8·50 | 8·00 | 9·08 |
| Steam coal . . | 5·30 | 11·00 | 7·75 | 7·50 | 8·59 |
| Gas coal . . | 7·52 | 13·47 | 11·75 | 10·13 | 11·46 |
| Foundry coke . | 10·36 | 22·00 | 14·63 | 14·00 | 16·25 |
| Blast-furnace coke | 9·16 | 19·78 | 12·00 | 11·00 | 14·00 |
| Briquettes . . | 7·81 | 14·64 | 14·38 | 9·75 | 11·21 |

Details are also given as to the production of coal and pig iron in the chief producing countries, and as to the varying prices of German iron in the period 1888–98.

The coalfield of the Ruhr district has made rapid progress in recent years. In 1888 the output was 33,223,614 tons, but in 1898 it reached 51,001,551 tons, an increase of 53·5 per cent. in ten years. The workpeople employed in and about the collieries in the former year numbered 105,445, while in 1898 they amounted to 191,215, an increase of 81·34 per cent. It will thus be seen that the increase in the output has not kept pace with that of the workpeople employed, and, consequently, that the output per miner has diminished. Notwithstanding this diminution in the output per miner employed, there has been a rise in the rate of wages paid.*

This field is further dealt with by R. Schneider.† He shows that the production of coke there is rapidly increasing, having been only 2,557,013 tons in 1886, while in 1896 it was 6,265,338 tons, and in 1897, 6,871,557 tons. In this latter year the total number of coke-ovens on the field was 7617, but at the close of 1898 this number had increased to 8082, of which 2100 were arranged for the collection of the by-products. In 1898 the output of coke increased to 7,374,320 tons, an increase of 7·3 per cent. as compared with the previous year. This district provides from 7 to 8 per cent. of the total quantity of the coke exported from Germany. In 1890 the German coke exports amounted to 1,074,755 tons, of the value of about £1,245,000, and by 1898 this increased to 2,133,179 tons, valued at £1,805,000. The 7,000,000 tons of coke made annually in the Ruhr district require some 9,000,000 tons of coal, and on the average over 1 per cent. of ammonium sulphate is obtained from this on coking. This would give a total of 90,000 tons a year as the output of ammonium sulphate on the field if all the coke-ovens were of the by-product collecting type, and the author considers that it will not be very long before all the coke-ovens in use on the field will be of this character. Ammonium sulphate contains about 20 per cent. of nitrogen, and Germany alone requires about 60,000 tons of nitrogen a year for agricultural purposes.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 250.

† *Ibid.*, pp. 269–270.

**Mineral Statistics of Luxemburg.**—The production of the Grand Duchy of Luxemburg for 1898 included 5,348,951 tons of iron ore, 110,898 tons of foundry pig iron, 603,134 tons of steel-making pig iron, and 134,995 tons of forge pig iron.

## VIII.—*GREECE.*

**Mineral Statistics.**—The mineral production of Greece in 1898[*] included:—

| | Quantity. | Value. |
|---|---|---|
| | Metric Tons. | Francs. |
| Iron ore . . . . . . . | 287,100 | 2,066,150 |
| Manganiferous iron ore . . . | 213,938 | 3,209,200 |
| Manganese ore . . . . . | 14,097 | 451,100 |
| Chrome ore . . . . . . | 1,367 | 90,000 |
| Magnesite, crude . . . . | 14,829 | 270,500 |
| Magnesite, calcined . . . | 129 | 5,800 |
| Magnesite bricks . . . . | 516 | 56,760 |
| Lignite . . . . . . . | 17,310 | 173,000 |

Mining undertakings in Greece are still confined to the small islands of the Cyclades and to the coast, transport facilities with the interior being inadequate. The average percentage of iron in the ore exported was 52.[†]

Manganiferous hæmatite or manganiferous iron carbonate is now found to be much more wide-spread in Laurium than was previously believed to be the case. Manganese ore is found in numerous places in Greece, but the deposits are usually so poor in manganese as to be worthless. The ore is only mined on the island of Milos, where it occurs as a bed in Tertiary volcanic tuff. By a simple system of washing the ore is freed from tuff and quartz, and a commercial product is obtained.

---

[*] *Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate*, vol. xlvii. pp. 225–227.

[†] *Stahl und Eisen*, vol. xix. pp. 751–752.

There has been considerable demand for Greek magnesite, and new workings have been consequently opened up near Chalkis and in Northern Eubœa, as well as on the mainland near Thebes.

## IX.—*INDIA.*

**Production of Coal.**—According to a circular issued by the India Office there were 174 coal-mines in operation in 1898, of which 158 were located in Bengal. The production in Bengal in 1898 exceeded 78 per cent. of the whole Indian production. The output in 1886 was 1,338,487 tons, and it has been increasing every year since that date. The industry gives employment to some 63,000 persons, and the capital invested in it by joint-stock companies amounts to Rs.1,148,323 (paid up); there is also a large but unknown investment of capital by private mine owners and by the State. The imports of coal, coke, and patent fuel in 1898–99 amounted to 359,010 tons.

That section of the Administration Report on the Railways in India for 1898–99 dealing with the coal-mines of India conveys the intelligence that the native coal supply of India was larger in the year covered by the present report than it was in any previous year. The output last year from the various coal-mines which have been opened in India reached 4,568,880 tons. The preceding year the output was 4,063,127 tons, while in 1885 the output only reached 1,123,700 tons. All the provinces, with the exception of Burma and the Punjaub, show an increase in the quantity of coal brought to the surface. The increase in Bengal was from 3,142,497 tons to 3,585,990 tons, in the Central Provinces from 131,629 tons to 149,709 tons, in Assam from 185,533 tons to 200,329 tons, in Central India from 124,778 tons to 134,726 tons, in the Nizam's territory from 365,550 tons to 394,622 tons, and in Baluchistan from 8876 tons to 10,667 tons. The Kurhurbaree and Serampore Colliery gave employment to 6512 persons as against 6113 in the preceding year, while the output of these two collieries increased from 454,021 tons to 461,544 tons. These collieries are worked in connection with the East Indian Railway, and their development has kept pace with the output, and is being pushed to meet the increasing demand. The Warora Colliery is worked by the Government, and has seven shafts; 862 persons found employment here last year, as compared with 821 employed in 1897–98. The output increased from 111,654 tons to 127,237 tons. This increase is chiefly due to the larger demands from the Great Indian Peninsula Railway and petty customers, owing to a more favourable cotton crop than in the previous year. The Umaria Colliery is also worked by the Government, and consists of sixteen pits and inclines. Here the average number of persons employed daily has fallen from 2617 to 1931 persons, while the output has increased from 124,778 tons to 134,726 tons, this increase being due to the extension of work. The Daudot Colliery, worked in connection with the North-Western State Railway, has fallen off somewhat, the number of persons employed daily being 1583 in 1898, as compared with 1997 in 1897, while the output fell from 79,646 tons to 74,590 tons. The decrease in the output is attributed to the scarcity of labour. The Baghanwala Colliery report is also an unfavourable one, the number of persons employed daily having fallen from 334 to 295, and the output showing a fall from 13,145 tons to 11,272 tons. The uncertain nature of the coal at the old mines is set down as the cause of the decrease. On the other hand, the Khost Collieries show an improvement, 237 persons having been employed daily in 1898, as compared with 217 persons in 1897. The output here increased from 8788 tons to 10,662 tons.

**Iron Manufacture.**—Major R. H. Mahon * has made a report on the manufacture of iron and steel in India. The questions treated relate to the available fuel, iron ores, and limestones, the coke obtainable from Indian coal, the sites of works, the trade and nature of output required, and the cost of out-turn. As appendices to the report are a report on the coking of Indian coal, an account of the Porto Novo Iron Company and its founder, J. M. Heath, of whom a portrait is given, extracts from a report of 1844, and notes on the harbours of Madras and Port Canning. The paper read by the author before the Institute and published in the present volume is practically a summary of the technical side of this report, which contains much information as to costs, freight, and so forth, but the details given are generally of a much fuller character. The causes to which the want of success of the Porto Novo Company were due are fully dealt with, and the report on the washing and coking of Indian coal, showing that in some instances good coke can be made, will prove of interest.

---

* *Report on the Manufacture of Iron and Steel in India*, Government Central Printing Office, Simla, 1899. A copy of the report is in the Library of the Institute.

It is stated* that the smelting and working of iron according to the native method is carried on in Central India in eleven districts—Saugor, Damoh, Jabalpur, Mandla, Seoni, Narsinghpur, Chanda, Bhandara, Balaghat, Sambalpur, and Raipur.

In Saugor there are six iron mines, which gave work during the past year to 1844 persons. In Damoh the smelting and refining is done by blacksmiths, who purchase the ore at a cost of a rupee for 54 maunds. Such of the metal as is not used by themselves is retailed to purchasers from the North-West Provinces, who convert it into cooking and other utensils for domestic use. The smelting process is crude but effective, a kiln made in the ground serving the purpose.

At Jabalpur the average number of furnaces at work throughout the working months of the past year was 28. During the working months, from November to May, 21 men on an average are employed at each furnace. These include woodcutters, charcoal-burners, ore extractors, furnace attendants, refiners, bellowsmen, and hammermen. A day's work varies from 33 to 50 seers of crude iron, locally known as "tickole" or "bloom," while the total amount turned out in the seven working months is about 275 maunds. The re-smelting of this bloom gives pig iron, which is locally known as "chandia." From 275 maunds of bloom 220 maunds of pig iron can be turned out.

The Mandla district has 51 furnaces, which produced during the year 1897 a total of 9 tons.

The smelting industry at Seoni during 1897 came to a standstill owing to the plague; while in the district of Narsinghpur, which is by no means rich in ore, comparatively little was done.

In the district of Chanda mining operations were carried on during 1897 in five separate localities. The ore, being quarried in big lumps, was afterwards broken up into pieces of convenient size and stacked in heaps for further use.

---

* *Indian Engineering*, vol. xxv. p. 139.

## X.—*ITALY.*

**Mineral Statistics.**—The mineral production of Italy* in 1898 comprised:—

| | No. of Works. | Production in Metric Tons. | No. of Workmen. |
|---|---|---|---|
| Pig iron | 8 | 12,387 | 247 |
| Wrought iron | 195 | 167,499 | 3181 |
| Steel | | 87,467 | |
| Mineral fuel | 28 | 341,327 | 2611 |
| Asphalt | 13 | 93,750 | 1252 |
| Iron ore | 20 | 190,110 | 1878 |
| Manganiferous iron ore | 1 | 11,150 | 160 |
| Manganese ore | 7 | 3,002 | 132 |
| Graphite | 15 | 6,435 | 122 |

The production of petroleum amounted to 2015 tons, and that of natural gas to 464,931 cubic metres. In 1898 there were in operation eight blast-furnaces.

**Iron Ore in Elba.**—Tonietti† gives some interesting particulars of the development of the iron ore mines of Elba. These mines, which belong to the Italian Government, have been leased from January 1, 1898, for a period of 20 or 25 years to the Chevalier Tonietti at a royalty of 7·25 francs per ton of ore exported, and of 0·50 franc per ton consumed in Italy. The concessionaire must not export to foreign countries more than 160,000 tons a year, and is obliged to supply the Italian ironmasters with at least 40,000 tons, including the consumption of the charcoal furnace at Follonica, in Tuscany, which he is expected to keep at work. His interest being to develop the production of pig iron in Italy, he has decided to build blast-furnaces in the island, and to further the construction of blast-furnaces at Piombino on the Tuscan coast, where there already exist steelworks and tinplate works. An Italian company has started a blast-furnace, and a French company has purchased land for the erection of large ironworks. The freight from Elba is 2s. to Piombino, 2s. 6d. to Follonica, 5s. 6d. to 7s. 6d. to Cardiff, and 7s. 6d. to 9s. 6d. to Middlesbrough or Rotterdam. In 1898 there were shipped 228,000 tons of ore, of which 110,000 tons went to England,

---

* *Rivista del Servizio Minerario*, Rome 1899.

† *Foreign Office Reports*, 1899, No. 2274; *Comité des Forges de France Bulletin*, No. 1462.

72,225 tons to Holland and Germany, 28,279 tons to France, and 16,785 tons to Italy. The average value of the ore exported was 13·75 francs a ton, inclusive of the royalty.

**The Iron Industry of Lombardy.**—The possibilities connected with the iron industry of Lombardy are discussed in an official report lately presented to the Italian Government.* The iron industry of Lombardy was at its maximum about forty years ago, when there were fifty active iron ore mines and twenty blast-furnaces in operation. Even then, however, the total out-turn was a very small one, only 34,000 tons of iron ore and 13,000 tons of an impure pig iron being produced. This latter yielded by the methods then in use not more than 9000 or 10,000 tons of iron and steel. The older methods of iron-making employed in the district are mentioned and details given as to the then cost of production In 1878 only twenty-five of the iron ore mines that were in operation in 1860 were still being worked, and the production of ore had fallen from 34,000 tons to 11,000 tons, and that of pig iron to 8000 tons. This sold for about 103 to 128 lire per ton, a price which did not equal the first cost of the metal. The iron industry has continued to dwindle away until now only some 1600 tons of ore are raised in the year, though the production of pig iron, owing to the using up of ore reserves, was 3000 tons. It is a difficult matter to decide as to the practicability of work on a large scale in the future in connection with the Lombardy iron ore deposits. This is due to the fact that although shallow workings are numerous, they do not admit of any judgment being formed as to what ore exists in the deep. Five iron ore regions are considered:—(1) The Val Trompia; (2) the Lower Camonica Valley and of Lake Iseo; (3) the Mid-Camonica Valley; (4) the Upper Scalve Valley; and (5) Manina and the Upper Seriana Valley. These extend from east to west in the Lombardy Alps. The geological conditions are mentioned under which the ores occur, and the ore deposits themselves are also described. The production of pig iron is next considered. The charcoal blast-furnaces that exist in Lombardy are very small, being from 33 to 39 feet in height, with a capacity of 424 to 494 cubic feet, and cannot make more than 3 to 4½ tons of pig iron a day, using blast of a temperature of 150° to 200° C. at a pressure of some 0·8 to 1 inch of mercury. Only one furnace is large enough to make from 8 to 10 tons a day. In 1872 there were 21 blast-furnaces in blast with an out-turn of 10,095 tons, but in 1896 the active furnaces only numbered 3, with an out-turn of 2932 tons. A good deal of the ore found is the carbonate.

---

* *Studio sulle Condizioni dell' Industria Siderurgica in Lombardia*, Rome, 1899. With map.

After considering various points connected with the manufacture and further treatment of pig iron in Lombardy, it is pointed out that it is unlikely that the ore deposits could ever yield on regular working more than about 30,000 tons of ore a year; and more than this, that it is improbable that pig iron made in Lombardy could be sold at prices which would enable it to compete with foreign or with Tuscan iron, except perhaps in the case of certain special kinds of foundry iron. The chief prospect seems to lie in the working up of scrap iron.

## XI.—*RUSSIA.*

**The Iron Industry.**—The consumption of iron in Russia is so enormous that it is no longer possible for the home ironworks to meet the demand, and metal has to be imported.* The metallurgical industry of the Urals is undergoing the most rapid development in the extreme northern portion of the district and in the south, whilst the central portion of the district has remained practically without any new developments. Blast-furnace plants are being erected in the north at Wishaichinsk and Aktschinsk, and in the south at Balaschewsk, Lemecinsk, and Archangelsk. Siberian coke can be delivered at Jekaterinenburg for 20 kopecks the pood. It has been decided to investigate the coal deposits near Pawlograd on the Irtisch in Siberia. New blast-furnaces and open-hearths have been erected in Central Russia, and the ore deposits at Kromy in the Orel government are to be developed. Several new undertakings in South Russia are also referred to. With regard to the various deposits of ore, borings have shown that the district south of the Krivoi Rog contains further ore bodies, but the quantity of ore has not yet been ascertained. Considerable deposits of iron ore, chiefly sphærosiderite, have been found in the neighbourhood of Ssaratov.

An economic investigation of the Russian iron trade has been published by Paul Trasenster.† The relative importance of the various districts is shown by the following statistics of pig iron production in 1897:—

---

* *Rigaer Industrie-Zeitung*, vol. xxv. p. 92; *Chemiker Zeitung*, vol. xxiii.; *Repertorium*, p. 251.

† *Revue Universelle des Mines*, vol. xlvi. pp. 151–213.

| | Tons. |
|---|---|
| South | 760,000 |
| Centre | 170,000 |
| Ural | 670,000 |
| Poland | 230,000 |
| St. Petersburg | 6,000 |
| Total | 1,836,000 |

According to the returns of the Russian Association of Ironmasters, the production in Russia in 1898 included 135,635,513 poods of pig iron, 30,457,383 poods of wrought iron, and 69,928,325 poods of steel.

The production of pig iron in the Ural in 1898* amounted to 42,790,000 poods, or 2,000,000 poods in excess of the output for the previous year. In 69 ironworks there were 115 active blast-furnaces. The progress made in the five years 1894–98 is shown from the following table:—

| | 1894. | 1898. |
|---|---|---|
| Active blast-furnaces | 113 | 115 |
| Pig iron produced, poods | 33,270,000 | 42,790,000 |
| Average production, poods | 293,000 | 371,000 |
| Average daily out-turn, poods | 803 | 1,016 |

Despite, therefore, the lack of transport facilities and of coal, it is evident that the pig iron industry in the Ural is making progress. The above table shows that during the five years the works' output has increased by 29 per cent., that of each blast-furnace by 26 per cent., and the average yield per day per furnace by 25 per cent.

An estimate of the production of pig iron in the Ural during the first half of 1899 places this at 23,600,000 poods, which would correspond to 47,200,000 poods for the whole year. This total will, however, probably be exceeded, and the out-turn reach some 48,000,000 or 49,000,000 poods, as six of the old blast-furnaces are undergoing improvement, and six new ones are in course of construction. The further progress of the industry is closely connected with the practicability of the works obtaining coke from Siberia.

According to Trasenster † the cost of manufacture of pig iron at the Jouriefka works amounts to about £5 per ton. This works is one of the best situated in Central Russia. There is a protective import duty on pig iron entering Russia to the extent of £3 a ton. The production of all kinds of pig iron in Russia in 1898 amounted, it is estimated, to 135,035,513 poods, as compared with a production of 113,982,000 poods in the previous year. The production of steel in Russia amounted to 69,928,325 poods in 1898, as compared with 52,964,000 poods in 1897. The production of merchant iron, sheets, and other finished products remained about the same in 1898 as it was in 1897.

---

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. p. 247

† *Echo des Mines et de la Métallurgie*, 1899, p. 5528.

**Manganiferous Pig Iron Industry.**—A. Foniakoff* has translated from the Russian an exhaustive memoir by Zeidler on the present condition and development of the manufacture of manganiferous pig iron in the south of Russia. The deposits of manganese ore of importance for the iron industry of the south of Russia are the Nicopol and the Caucasus deposits. The deposit of pyrolusite at Nicopol, to the west of the town of that name, has not yet been fully investigated. The ore, which is washed and screened, contains 30 to 35 per cent. of manganese; after concentration it contains 42 to 51 per cent. of manganese. The ore, besides being poor, contains phosphorus. It is brought by mules to Nicopol, whence it is sent by boat to Alexandrowsk, a railway station on the Dnieper. In 1897 there was sold 3,330,000 poods of this ore. The Caucasus manganese ore forms a horizontal bed two yards in thickness. It is worked by small galleries driven in the bed itself, and a large proportion of the ore is left there in the form of pillars. The ore contains 50 to 55 per cent. of manganese. The Caucasus deposits are connected with the Transcaucasian Railway, the ore being thus easily transported to Poti, on the Black Sea. The exports from Poti amounted in 1897 to 11,441,000 poods. The authors passing on to the manganiferous pig iron industry, shows that Russia consumes 3,400,000 poods of such pig iron annually, of which amount 1,200,000 poods are imported. Seeing that Russia supplies Europe with 60 per cent. of the manganese it needs, and is forced to import manganiferous pig iron, it is obvious that the manufacture of spiegeleisen in Russia would certainly be a profitable undertaking. The Nicopol ores might be used exclusively for the manufacture of low-grade spiegeleisen and ordinary forge pig iron, whilst those of the Caucasus would serve for the manufacture of high-grade ferro-manganese, for the needs of the country and for exportation.

---

* *Revue Universelle des Mines*, vol. xlvii. pp. 69–77.

**The Coal Industry.**—The number of coke-ovens in the Donetz coal basin amounted in December 1898 to 2758.* Of these, 400 were at the Jusowka works, while twelve works each possessed over 100 ovens, the others each owning less than that number. Allowing a daily production from each oven of 120 poods, the out-turn of coke in the Donetz basin would thus amount to over 119,000,000 of poods yearly. L. J. Lutugin, in a paper read before the Society for the Promotion of Industry and Trade in Russia, describes the progress made by the Donetz basin. He shows that the deposits of both coking coal and anthracite are very great, the latter being especially abundant. The question of the proper utilisation of these anthracite deposits is a matter of the greatest importance.

Coal deposits of considerable importance have been discovered on the Miass River to the north-east of the town of Tscheljabinsk. The coal is stated to contain only 4 per cent. of ash. The chief importance of this discovery lies in the fact that these are the only coal deposits yet discovered in the Southern Ural. A railway runs close to this new coalfield. The Ssudschenki coal seams, near the Taiga station on the Mid-Siberian Railway, are also stated to be rich. At present they yield 2500 poods of coal a day, but this production is shortly to be made ten times as large.

**The Southern Ural Mining Industry.**—M. Busemann† observes that new railway construction will shortly open up the Southern Ural in such a manner as to admit of an iron industry on a large scale being developed. Apart from a small and unimportant group of blast-furnaces smelting local ores, mining does not at present exist in this district, and the almost inexhaustible iron ore deposits have so far not been worked. Magnetite, brown iron ore, chrome iron ore, and ores of manganese and of copper are all found. The brown iron ores in particular are of excellent quality. They are easily reduced, and contain scarcely any deleterious constituents. They average from 50 to 55 per cent. of iron, and can almost everywhere be mined open-cast. The use of charcoal as fuel is still possible in places, but in other districts coke is a necessity. Indeed the gradual transition from charcoal to coke is throughout the whole of the Ural merely a matter of time, or rather of the near future.

---

* *Rigaer Industrie Zeitung*, vol. xxv. p. 164.

† *Stahl und Eisen*, vol. xix. pp. 341–342.

## XII.—*SPAIN.*

**Iron Trade Statistics.**—The output of iron and steel in Spain * in 1898 was as follows:—

| | Metric Tons. |
|---|---|
| Pig iron | 261,799 |
| Bessemer steel ingots | 54,500 |
| Open-hearth ingots | 58,105 |
| Finished iron and steel | 154,910 |

Of the pig iron produced, 16,000 tons were made with charcoal.

**Imports and Exports.**—The Spanish imports in 1898 included: †—

| | Metric Tons. |
|---|---|
| Coal | 1,215,554 |
| Coke | 231,467 |
| Pig iron | 1,575 |
| Iron and steel | 2,583 |
| Petroleum | 32,468 |
| Tin plate | 653 |

The exports during the same year included:—

| | Metric Tons. |
|---|---|
| Coal | 2,772 |
| Iron ore | 6,478,488 |
| Manganese ore | 138,062 |
| Iron and steel | 46,129 |

## XIII.—*SWEDEN.*

**Iron Trade Statistics.**—The Swedish official mineral statistics for 1898 have been issued by Dr. Åkerman, the director-general of the Board of Trade.‡ The Swedish production comprised:—

| | Metric Tons. |
|---|---|
| Iron ores | 2,302,914 |
| Pig iron, all made with charcoal | 531,766 |
| Blooms produced from pig iron in charcoal hearths | 198,923 |
| Bessemer ingots and castings | 102,254 |
| Open-hearth ingots and castings | 160,706 |
| Crucible ingots and castings | 1,013 |
| Blister steel | 1,148 |
| Bar iron and steel | 170,374 |

---

* *The Mineral Industry*, vol. vii. p. 404.

† *Anuario de la Mineria de España; The Mineral Industry*, vol. vii. p. 859.

‡ *Kommerskollegii underdaniga berättelse*, 1899.

| | Metric Tons. |
|---|---|
| Nail and wire rods, band iron and steel | 101,250 |
| Otherwise shaped iron and steel in bars | 9,548 |
| Plates (not including sheets) | 16,530 |
| Tube blocks, hollow blooms, and billets | 11,692 |
| Coal | 236,277 |
| Number of blast-furnaces in blast | 143 |
| Average daily product per furnace, tons | 13·35 |
| Average time per furnace in blast, days | 279 |

**Shipments of Iron Ore.**—The shipments of Gellivare iron ore from the port of Luleå ceased for 1899 early in November, the shipments having been as follows:—

| To | Tons. |
|---|---|
| West Germany | 491,384 |
| East Germany | 214,402 |
| England | 123,407 |
| Belgium | 69,855 |
| France | 11,476 |
| Finland | 1,047 |
| Sweden | 9,426 |
| Total | 920,997 |

The shipments during the preceding seven years were as follows:—

| Year. | Tons. |
|---|---|
| 1892 | 138,944 |
| 1893 | 259,826 |
| 1894 | 524,112 |
| 1895 | 385,781 |
| 1896 | 614,262 |
| 1897 | 815,797 |
| 1898 | 804,733 |

The shipments of Grängesberg ore from Oxelösund continue to the end of the year, the quantity exported being 585,000 to 600,000 tons.*

**Production of Coal.**—The output of coal in Sweden † in 1898 was 236,277 tons, and that of fireclay 131,391 tons. The number of miners employed was 1271. The output of the various collieries was as follows:—

| Colliery. | Shafts. | Coal. | Fireclay. |
|---|---|---|---|
| | | Tons. | Tons. |
| Skromberga | | 49,654 | |
| Boserup | | 800 | |
| Höganäs | | 59,410 | 42,782 |
| Billesholm | | 76,501 | 29,708 |
| Ljungsgarda | | 4,915 | 8,835 |
| Bjuf | | 44,908 | 42,446 |
| Stabbarp | | 89 | 7,620 |

---

* Communicated by Mr. John Johnson of the Frövi-Ludvika Railway, November 11, 1899.

† *Kommerskollegii Underdaniga Berättelse,* 1899, p. 12.

J. Mauerhofer[*] observes that coal was mined in Sweden in 1737 about six miles to the south-east of Helsinborg. At Höganäs five very narrow seams are being worked. These are separated by clay partings from 7 to 18 inches in thickness. The five seams themselves only total 16 inches of coal when taken together. Beneath there is about 11½ feet of excellent fireclay. At Bjuf and Billesholm are three seams of coal of poor quality as regards ash, and about a yard in thickness taken together, which are separated by wide partings of clay and sandstone. In places the conditions are slightly more favourable. It is the fireclay on which the commercial success of the undertakings depends, the coal itself being secondary as a source of revenue. At Bjufa, a large pumping plant is being put down at one of the shafts, which is intended to be used as a central pumping station for the whole of the adjacent district. No difficulties are experienced either from firedamp or coal-dust. At Höganäs no explosives are employed, but at Bjuf dynamite is occasionally used.

**Swedish Iron Metallurgy and its Application to Canada.**—J. Douglas[†] gives some notes on Swedish iron manufacture, and its application to Canada. The conditions that obtain in Sweden are described, and some account is given of the ores, fuel, and the different ironworks. Amongst the discussion is a communication by E. A. Sjostedt emphasising the features of economy in fuel and the quality of the products.

## XIV.—*SWITZERLAND.*

**Production of Coal.**—The Swiss Government has recently devoted considerable attention to the coal resources of the Republic. In the Canton of Zürich, at Käpfnach, coal has been mined for more than 150 years. It is of Tertiary age, the seam being 1 to 1½ foot in thickness. The output is at present consumed in the local Portland cement works. There are several unworkable deposits of lignite in the Canton of Zürich. At Unter-Wetzikon and at Dürnten, indeed, lignite was mined for several years without covering the cost. In the Canton of St. Gall there is a lignite mine in operation at Utznach, at the Lake of Zürich, and another at Mörschwyl, near the Lake of Constance. In 1860, at Utznach, some 3200 tons were raised, but of late the production has fallen to 600 tons annually. Lignite is also met with in the Cantons of Bern, Freiburg, and Vaud, and has been worked here and there on a small scale. Valais is, however, the only canton in which coal measures with workable seams occur. The mines which work a seam of anthracite are on the left bank of the Rhone. The two mines, Chandoline and Granges, yield 1500 to 2000 tons annually of an anthracite containing 6 to 12 per cent. of ash. The seam has been much faulted, so that the produce is suitable only for lime-burning and for cement manufacture. A variety of graphite, the properties of which are intermediate between graphite and anthracite, is met with in the carboniferous shales of the Canton of Valais. The mines which are at Iserables yield annually 3000 tons of a material that is used for moulding in foundry practice.*

---

[*] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xlvii. pp. 330–331, and 346–348; with illustrations.

[†] *Journal of the Canadian Mining Institute*, vol. ii. pp. 38–53 and 213–226.

---

## XV.—*UNITED STATES.*

**Iron Trade Statistics.**—According to the returns of the American Iron Trade Association † the production of pig iron in the United States during the first half-year of 1899 was 6,289,167 tons. Complete iron trade statistics for 1898 have been published. ‡

**Mineral Statistics.**—The mineral production of the United States in 1898 is stated § to have included:—

| | Tons. |
|---|---|
| Iron ore | 20,655,865 |
| Manganese ore | 217,782 |
| Bauxite | 26,791 |
| Chrome ore | 100 |
| Limestone flux | 5,275,819 |

The production of petroleum was 51,774,465 barrels.

**Blast-Furnaces.**—The following table ‖ gives the number and capacity of furnaces in and out of blast in the United States on July 1, 1899:—

| Fuel. | In Blast. | | Out of Blast. | |
|---|---|---|---|---|
| | No. | Weekly Capacity. | No. | Weekly Capacity. |
| Charcoal | 21 | 5,915 | 53 | 9,559 |
| ite and coke | 49 | 33,212 | 46 | 23,165 |
| ious and coke | 164 | 217,751 | 70 | 49,140 |
| | 234 | 256,878 | 169 | 81,864 |

---

* *Zeitschrift für praktische Geologie*, 1899, pp. 220–224.

† *Bulletin*, vol. xxxiii. p. 133.

‡ *United States Geological Survey*, *Nineteenth Annual Report.*

§ *The Mineral Industry*, New York, vol. vii. p. 9.

‖ *American Manufacturer*, Supplement, July 13, 1899.

**Iron Ore in Michigan.**—The fifteenth annual report of the Bureau of Labour and Industrial Statistics of Michigan contains full details of the number of mines and mine workers, occupations, wages, output, and other data regarding the mines of the State. Thirty-three iron mines in 1897 produced 5,933,005 tons of ore, and gave employment to 8931 persons, paying an average wage of 6s. 7d. per day.

**Coke Production.**—According to the report of Mr. E. W. Parker, statistician of the United States Geological Survey, the coke production of the United States in 1898 amounted to 16,047,209 short tons (of 2000 lbs.), against 13,288,984 short tons in 1897. The increase in the product of 1898, as compared with the preceding year, was 2,758,225 short tons, or 21 per cent. Prior to 1898 the maximum yearly product was obtained in 1895, when the output amounted to about 45,000 tons more than that of 1897.

**Conditions of the Iron and Steel Industries.**—W. Dixon * offers a few remarks on some conditions of the American iron and steel industries. Amongst other things, he notes the comparative youth of many of the men who hold important positions at the head of the large works, the greater incentive to invention and its encouragement, the higher rate of wages but greater out-turn of the workmen, making labour cost less on the whole in respect of the piece as compared with this country, labour-saving machinery, the extended use of electric appliances, and the resources of the different districts.

A. Brown † discusses the effect on the American iron industry of the recent advance of prices, and endeavours to prognosticate the future course of affairs.

**Metallurgical Education.**—Professor H. M. Howe ‡ discusses the equipment of metallurgical laboratories, and points out that the use in them of full-sized appliances is not of much value if they are simply regarded as means for anticipating practical experience in works. Smaller and simpler furnaces and other appliances will fulfil all the requirements of the case, and they should be regarded as pegs on which to hang explanations of theories, in that they can be so easily induced to work badly. They may, however, be used to show the nature of the remedies that will have to be employed when the student comes to carry out operations on a large scale. Though the author deprecates to some extent the use of large appliances, he does not altogether wish to dispense with them, but, on the whole, he seems to prefer laboratory instruction with models and substitutes, amplified by full technical and theoretical instruction as given by lectures.

---

* *Cassier's Magazine*, vol. xvi. pp. 185–190.

† *Engineering Magazine*, vol. xviii. pp. 83–92.

‡ *Transactions of the American Institute of Mining Engineers*, February 1899.

R. P. Rothwell * deals with correspondence schools.

## XVI.—*COMPARATIVE TABLES.*

**The World's Production of Coal and Iron.**—For purposes of comparison, the following summary of the production of coal in the principal countries of the world is appended :—

| Country. | Year. | Production in Tons. |
|---|---|---|
| United Kingdom . . . . | 1898 | 202,054,516 |
| Australia— | | |
| New South Wales . . . | 1898 | 4,706,251 |
| New Zealand . . . . | 1897 | 840,713 |
| Queensland . . . . | 1897 | 358,407 |
| Tasmania . . . . . | 1897 | 48,501 |
| Victoria . . . . . | 1898 | 242,859 |
| Austria, coal . . . . | 1898 | 10,947,521 |
| ,, lignite . . . . | 1898 | 21,083,360 |
| Hungary, coal . . . . | 1897 | 1,132,624 |
| ,, lignite . . . . | 1897 | 3,876,223 |
| Belgium . . . . . . | 1898 | 22,088,335 |
| Borneo . . . . . . | 1897 | 41,587 |
| Bosnia . . . . . . | 1898 | 271,184 |
| Canada . . . . . . | 1898 | 3,785,408 |
| Cape Colony . . . . . | 1897 | 113,851 |
| France . . . . . . | 1898 | 32,439,786 |
| Germany, coal . . . . | 1898 | 96,279,992 |
| ,, lignite . . . . | 1898 | 31,648,498 |
| Greece . . . . . . | 1898 | 17,310 |
| Holland . . . . . . | 1896 | 137,787 |
| India . . . . . . | 1898 | 4,568,880 |
| Italy, lignite . . . . | 1898 | 341,327 |
| Japan . . . . . . | 1897 | 6,000,000 |
| Mexico . . . . . . | 1896 | 253,104 |
| Natal . . . . . . | 1898 | 387,811 |
| Peru . . . . . . | 1892 | 2,000 |
| Portugal, anthracite . . . | 1897 | 7,996 |
| ,, lignite . . . . | 1897 | 9,342 |
| Russia . . . . . . | 1898 | 12,114,754 |
| Servia . . . . . . | 1896 | 11,726 |
| South African Republic . . | 1898 | 1,953,026 |
| Spain . . . . . . | 1898 | 2,466,800 |
| Sweden . . . . . . | 1898 | 236,277 |
| United States . . . . | 1898 | 196,405,953 |

---

*Transactions of the American Institute of Mining Engineers*, February 1899.

A similar summary showing the production of pig iron is as follows:—

| Country. | Year. | Production in Tons. |
|---|---|---|
| United Kingdom . . . . . | 1898 | 8,609,719 |
| Austria. . . . . . . | 1898 | 957,836 |
| Hungary . . . . . . | 1897 | 384,345 |
| Bosnia . . . . . . . | 1898 | 15,366 |
| Belgium . . . . . . | 1898 | 979,755 |
| Canada . . . . . . . | 1898 | 68,755 |
| France . . . . . . . | 1898 | 2,534,427 |
| Germany and Luxemburg . . | 1898 | 7,402,717 |
| Italy . . . . . . . | 1898 | 12,387 |
| Japan . . . . . . . | 1896 | 16,000 |
| Russia . . . . . . . | 1898 | 2,193,750 |
| Spain . . . . . . . | 1898 | 261,799 |
| Sweden. . . . . . . | 1898 | 531,766 |
| United States . . . . . | 1898 | 11,773,934 |

**The World's Production of Steel.**—James M. Swank,* the general manager of the American Iron and Steel Association, gives the following table, showing the production of steel in all countries in 1898, or in the most recent year for which statistics have been received. English tons of 2240 lbs. are used for Great Britain, Canada, and the United States, and metric tons of 2204 lbs. for all other countries, metric tons being used as the equivalent of English tons in ascertaining the total production for all countries.

| Countries. | Steel. | | |
|---|---|---|---|
| | Year. | Production. | Per Cent. |
| | | Tons. | |
| United States. . . . . . | 1898 | 8,932,857 | 37·05 |
| Great Britain. . . . . . | 1898 | 4,665,986 | 19·35 |
| Germany and Luxemburg | 1898 | 5,779,570 | 23·97 |
| France . . . | 1898 | 1,473,100 | 6·11 |
| Belgium . . . | 1898 | 653,130 | 2·71 |
| Austria and Hungary | 1896 | 880,696 | 3·65 |
| Russia and Finland | [illegible] | 1,145,758 | 4·75 |
| Sweden . . . | 1898 | 265,121 | 1·10 |
| Spain . . . | 1898 | 213,015 | 0·89 |
| Italy . . . | 1897 | 63,940 | 0·27 |
| Canada . . . | 1898 | 21,540 | 0·09 |
| Other countries . | 1898 | 15,287 | 0·06 |
| Total | | 24,110,000 | 100·00 |

**The World's Production of Iron Ore and Pig Iron.**—On the usually accepted basis of two tons of ore to a ton of pig iron, the iron output of the world for 1898 represents 70,000,000 tons of ore, and in 1899 if the estimated quantity of iron is produced, another six million tons of ore will be required. The ratio of two to one is, however, too low, as in the United Kingdom nearly 20,000,000 tons of ore were absorbed and 8,631,151 tons of iron produced. Probably at least eighty million tons will therefore be required, and it is becoming a serious problem to find the means of supply of ore of suitable quality, and the conclusion is drawn that pig iron is bound to rise in value.[*]

---

* *Bulletin of the American Iron and Steel Association*, vol. xxxiii. p. 196.

An exhaustive statistical paper on the world's production of iron ore and pig iron has been published by Kupelwieser.[†] Detailed statistics are given for each country for a long series of years, and it is shown that the world's production of iron ore increased from 28,254,000 tons in 1870 to 65,913,000 tons in 1876. Similarly, the world's production of pig iron increased from 12,019,000 tons in 1870 to 33,357,000 tons in 1897. J. S. Jeans [‡] also discusses the world's consumption of pig iron in the steel industry from a statistical point of view; and as bearing to some extent on the occurrence of iron ore in the world, it may be noted that details of the geological surveys of various countries are given by James Stirling. [§]

**The World's Production of Manganese Ore.**—Guillermo Sundheim [‖] publishes an exhaustive article on the world's production of manganese ore. The exports last year comprised :—

| From | To Europe. | To America. | Total. |
|---|---|---|---|
| | Tons. | Tons. | Tons. |
| Caucasus | 165,636 | 42,171 | 207,807 |
| South America | 2,500 | ... | 2,500 |
| Turkey and Greece | 18,145 | 21,178 | 39,323 |
| Spain and Portugal | 138,675 | ... | 138,625 |
| France | 18,225 | ... | 18,225 |
| Japan | 2,895 | 6,698 | 9,593 |
| Java | 3,451 | ... | 3,451 |
| India | 51,346 | 5,944 | 57,290 |
| Brazil | 8,720 | 12,870 | 21,590 |
| Chili | 11,377 | 14,130 | 25,507 |
| Panama | ... | 10,700 | 10,700 |
| Totals | 420,970 | 113,691 | 534,611 |

---

[*] *The Statist*, vol. xliii. pp. 756-757.

[†] *Zeitschrift des Oesterreichischen Ingenieur und Architechten Vereines*, vol. li. pp. 355-371, 381-387.

[‡] *Iron Age*, June 1, 1899, pp. 14-15.

[§] Paper read before the Australian Institute of Engineers through the *Iron and Coal Trades Review*, vol. lix. pp. 566, 706.

[‖] *Revista Minera*, vol. l. pp. 415-416.

To these totals there has to be added the production consumed in the countries producing the ore, an amount which is approximately as follows:—

| | Tons. |
|---|---|
| France | 17,000 |
| Austria-Hungary and Bosnia | 11,000 |
| Germany | 42,000 |
| Italy | 1,500 |
| Sweden | 3,000 |
| England | 1,200 |
| Belgium | 20,000 |
| United States | 50,000 |
| Total | 145,700 |

The world's consumption is thus about 680,300 tons.

With the exception of the Belgian ores, the Spanish ores are the poorest, not exceeding 35 per cent. of manganese. The ores of the Caucasus, India, and America average 50 per cent. of metal.

**The World's Production of Petroleum.**—R. Kissling* discusses the progress made by the petroleum industry during the year 1898, and refers to the various publications relating to petroleum which have recently appeared. The various places at which petroleum has been found are briefly mentioned. World's statistics are given for the year 1897, and a brief summary is given generally of all recent information which has appeared in connection with the petroleum industry.

**The World's Railways.**—Details are given † showing the progress made in railway construction during each of the years 1893 to 1897. These comprised in kilometres:—

| | 1893. | 1894. | 1895. | 1896. | 1897. |
|---|---|---|---|---|---|
| Europe | 238,478 | 245,139 | 251,421 | 257,540 | 263,145 |
| America | 360,842 | 364,975 | 370,321 | 374,873 | 380,384 |
| Asia | 38,995 | 41,970 | 43,375 | 46,549 | 49,764 |
| Africa | 12,379 | 13,103 | 13,147 | 14,827 | 15,948 |
| Australia | 21,199 | 22,202 | 22,349 | 22,372 | 23,014 |
| Totals | 671,893 | 687,389 | 700,613 | 716,161 | 732,255 |

It will be seen that the increase in each year was about 2 per cent. over that for the year preceding. In Europe in 1897 Germany had the greatest length of railways, 48,116 kilometres; France being second, with 41,342 kilometres; Russia third, with 40,262; the United Kingdom fourth, with 34,445; and Austria-Hungary fifth, with 33,668. The increase has been as follows in the countries named during the period 1893 to 1897 :—

---

* *Chemiker Zeitung*, vol. xxiii. pp. 717–720.

† *Stahl und Eisen*, vol. xix. pp. 630–633.

| | Increase per Cent. |
|---|---|
| Russia | 20·2 |
| Austria-Hungary | 15·4 |
| Italy | 10·1 |
| Germany | 7·3 |
| France | 5·0 |
| United Kingdom | 3·6 |

Italy in 1897 had 15,643 kilometres of railways, Spain 12,916, Sweden 10,169, and Belgium 5904. No other country of Europe had 4000.

In British India the progress in railway construction has been rapid, and in 1897 there were in existence there 33,820 kilometres, while Ceylon had a further length of 478 kilometres. In Australia the percentage increase from 1893 to 1897 was 8·5. In Victoria in 1897 there were 5035 kilometres, New South Wales being second among the Australian colonies with 4383.

# BIBLIOGRAPHY.

The following is a list of the principal works relating to iron and steel published during the second half of 1899:—

## METALLURGY.

**BECKERT, T.** "*Kerpely's Bericht über die Fortschritte der Eisenhüttentechnik im Jahre* 1894." 8vo, pp. 224, with 176 illustrations. Leipzig. (Price 12s.)

**BERSCH, J.** "*Lexicon der Metall-Technik.*" 8vo. Vienna: Hartleben.

**DAFERT, F. W., and O. REITMAIR.** "*Die Bewerthung des Thomasschlackenmehles.*" Vienna.

**EWING, J. A.** "*The Strength of Materials.*" 8vo. Cambridge. (Price 10s.)

**GAGES, L.** "*Essai sur la Théorie Générale des Aciers.*" Nancy. (Price 2s.)

**GLAZIER, R.** "*A Manual of Historic Ornament.*" 8vo, with 470 illustrations. London: B. T. Batsford. (Price 5s.)

**KIRK, E.** "*The Cupola Furnace.*" A practical treatise on the construction and management of foundry cupolas. 8vo, pp. 361, with 78 engravings. London: E. & F. N. Spon.

**KLEY, W.** "*Bei Krupp. Eine Socialpolitische Reiseskizze under besonderer Berücksichtigung der Arbeiter-Wohnungsfürsorge.*" 8vo. Leipzig. (Price 3s. 6d.)

**KOEPPER, G.** "*In Pluto's Reich. Wanderungen durch Schlacht und Hütte im Rheinish-Westfälischen Industriebezirke.*" With 49 plates. Berlin. (Price 5s.)

**LEDEBUR, A.** "*Handbuch der Eisenhüttenkunde.*" 3rd edition. Part II. 8vo. Leipzig: A. Felix. (Price 13s.)

**LEDENT, L.** "*Traité Pratique de la Fonderie de Fer.*" 2nd edition, with 85 illustrations. Liége. (Price 8s.)

**LEWIS, J. S.** "*The Commercial Organisation of Factories.*" 8vo, pp. 576, with diagrams. Eccles, Lancashire: J. S. Lewis. (Price 21s.)

**MAHON, R. H.** "*A Report on the Manufacture of Iron and Steel in India.*" Pp. 39 and 18, with maps. Government Central Printing Office, Simla.

**PÜTSCH, A.** "*Neuere Gas- und Kohlenstaubfeuerungen.*" Berlin: L. Simion. (Price 4s.)

**ROTHWELL**, R. P. "*The Mineral Industry.*" Vol. VII. 8vo, pp. 909, illustrated. New York: The Scientific Publishing Co. (Price 25s.) This volume contains the mineral statistics of the United States and other countries for 1898, together with notes on the progress of iron and steel metallurgy by H. M. Howe, and a report on the progress of metallography in 1898 by A. Sauveur.

**SCHOPPMANN**, R. "*Eisen und Stahl.*" 8vo. pp. 48. Leipzig: B. F. Voigt. (Price 1s. 2d.)

**TREPTOW**, E., F. **WÜST**, and W. **BORCHERS**. "*Bergbau und Hüttenwesen.*" 8vo, pp. 605, with 608 illustrations and 12 plates. Leipzig: O. Spamer. (Price 8s.)

## MINING.

**AGUILERA**, J. G. "*Catalogos Sistematico y Geografico de las Especies Mineralogicas de la Republica Mexicana.*" 8vo, pp. 160. City of Mexico: State Printing Office.

**BALLING**, C. "*Ueber die Ermittlung des Substanzverlustwerthes beim Bergbau.*" Teplitz-Schönau: A. Becker.

**BELL**, B. T. A. "*The Canadian Mining Manual and Mining Companies' Yearbook.*" 8vo, pp. 658. Ninth year. Ottawa: Slater Building.

**BÖCKH**, J., and A. **GESELL**. "*Angabe der im Betriebe stehenden und im Aufschlusse begriffenen Lagerstätten von Edelmetallen, Erzen, Eisensteinen und Mineralkohlen auf Territorium der Länder der ungarischen Krone.*" Budapest. (Price 8s. 6d.)

**BOYLE**, P. C. "*Derrick's Handbook of Petroleum.*" A complete chronological and statistical review of petroleum developments from 1859 to 1898. Derrick Pub. Co., Oil City, Pennsylvania.

**BROWN**, M. "*Gradation for Mine Management.*" Wigan: Thos. Wall & Sons. (Price 1s. 6d. net.)

"*Comité Central des Houillères de France: Annuaire* 1899." Paris: Published at the Office of the Comité, 55 Rue de Châteaudun. (Price 2s. 5d.)

**CONTRERAS**, A. "*Annuario de la Mineria, Metalurgia y Electricidad de España.*" Vol. VI. Madrid. (Price 8s.)

**DAHLBLOM**, M., and P. **UHLICH**. "*Ueber Magnetische Erzlagerstätten und deren Untersuchung durch Magnetische Messungen.*" 8vo, pp. 68, illustrated. Freiberg, Germany: Craz & Gerlach. (Price 2s. 6d.)

**DAY**, D. T. "*Nineteenth Annual Report of the United States Geological Survey.*" 1897–98. Part VI.: Mineral Resources of the United States, 1897: Metallic Products, Coal and Coke; Non-Metallic Products, except Coal and Coke. 2 vols. Washington: Government Printing Office.

"'*Don'ts' for Miners.*" A Practical Book for Practical Men. Cardiff: *Western Mail Limited.* (Price 3d.)

Dufrane-Demanet, A. "*Traité d'Exploitation des Mines de Houille.*" In 3 vols., with 750 figures in the text. Brussels: Société Belge d'Editions. (Price 24s.)

"*Eighth Biennial Report of the Inspector of Coal Mines of the State of Colorado.*" 1897–98. Denver: The Smith-Brooks Printing Company.

Elsden, J. V. "*Applied Geology.*" Part II., with numerous illustrations. London: "The Quarry" Publishing Company Limited.

Fauck, A. "*Fortschritte in der Erdbohrtechnik.*" 2nd edition. 8vo, with 31 illustrations. Leipzig. (Price 3s. 6d.)

Frech, F. "*Die Steinkohlen Formation.*" 8vo, with 9 plates, 3 maps, and 99 illustrations. Stuttgart. (Price 18s.)

Gürich, G. "*Das Mineralreich.*" 8vo, pp. 754, with 521 illustrations. Neudamm, Brandenburg. (Price 7s. 6d.)

Kirschner, L. "*Grundriss der Erzaufbereitung.*" Part II. 8vo. Vienna: F. Deuticke. (Price 9s.)

Lamprecht, R. "*Die Grubenbrandgewältigung.*" 8vo, pp. 144, with 7 lithographed tables. Leipzig: Arthur Felix. (Price 7s.)

M'Neill, B. "*Terminal Index for Use with M'Neill's Code.*" London: Whitehead, Morris & Co., Limited. (Price 7s. 6d.)

Michell, S. "*Mine Drainage.*" 2nd edition. 8vo, pp. 388, with 250 illustrations. London: Crosby Lockwood & Son. (Price 25s. net.)

Neuburger, H., and H. Noalhat. "*Technologie du Pétrole.*" Vol. I. 8vo, illustrated. Paris. (Price 36s.)

Paniowski, A. "*Die Montanindustrie Oberschlesiens vor 100 Jahren.*" Kattowitz: G. Siwinna. (Price 10d.)

Schneider, G. "*Der Braunkohlen-Bergbau in den Revierbergamts-Bezirken Teplitz, Brüx und Komotau.*" 8vo. Teplitz. (Price 4s.)

"*Studio sulle Condizioni dell' Industria Siderurgica in Lombardia.*" 8vo, pp. 48, with map. Rome: National Printing Office.

Sutherland, D. A. "*The Petroleum Industry of Roumania.*" With illustrations and a map showing the petroleum fields and intersecting railways. London: Paul Dvorkovitz, 16 Devonshire Chambers, Bishopsgate Street.

"*Uebersichtskarte der Eisenbahnen im Ruhrkohlengebiet mit Zechen, Schächten und Werken.*" 5th edition. Hagen. (Price 4s.)

Weidtman, Dr. "*Jahrbuch für den Oberbergamtsbezirk Dortmund.*" 8vo. Essen: G. D. Baedeker. (Price 10s.)

White, I. C. "*West Virginia Geological Survey.*" Vol. I. Containing "Administrative Report," "Levels above Tide," and "Petroleum and Natural Gas." Morgantown, West Virginia: Printed for the Survey. Pp. 392.

Zycha, A. "*Das Recht des ältesten deutschen Bergbaues.*" 8vo, pp. 172. Berlin: F. Vahlen. (Price 4s.)

# INDEX.

A.

ACCIDENTS in mines, 496.
Acheson, E. G., on graphite, 337.
Action of sea-water on iron, 474.
Action of water on galvanised iron, 474.
Adamson, Harold, elected member, 5.
Adamson, Joseph, & Company's works, 269.
Additions to the Library, 297.
Age of iron ore veins, 306.
Ainsworth, George, on a new casting-machine for blast-furnaces, 63.
Åkerman, R., on Swedish iron trade statistics, 520.
Alabama, iron ore in, 320.
Albree, C. B., on ornamental ironwork, 448.
Algeria, coal in, 350.
Algerian iron ore, 505.
Alloys of iron and nickel, 462.
Aluminium as a reducing and heating agent, 475.
American collieries, 392.
American open-hearth steelworks, 437.
Ami, H. M., on petroleum in Canada, 361.
Anderson, D., on by-product ovens, 353.
Anthony, U., on the determination of sulphur in coal, 492.
Anvils, the manufacture of, 447.
Armour-plates, tests of, 471.
Artificial gas, 365.
Aschman, C., on the determination of phosphoric acid in basic slag, 491.
Ashton, A. W., on the magnetic properties of iron and steel, 455.
Asia Minor, coal in, 350.
Athabasca Landing, natural gas at, 364.
Atkinson, Isaac, on coal-cutting machinery, 374.
Aulich on the determination of sulphur, 486.
Australasia, statistics of, 496.
Australia, manganese ore in, 318.
Austria-Hungary, iron trade exports and imports of, 497.
Austria-Hungary, statistics of, 496.
Austrian collieries, 389.
Austrian crucible steelworks, 432.
Austrian Silesia, coal in, 343.

B.

BAACKES, FRANK, elected member, 5.
Babu, L., on the evolution of the blast-furnace, 408.
Bach, C., on standard tests of cast iron, 468.
Bach, C., on the tests of steel, 469.

Bachman, F. E., on silicon and carbon in cast iron, 409.
Bachman, F. E., on slips and explosions in the blast-furnace, 398.
Bain, H. F., on coal-cutting machinery, 374.
Barillon on diamond boreholes, 328.
Barraclough, S. H., on the alloys of iron and nickel, 464.
Barrett, W. F., on the alloys of iron and nickel, 463.
Barrett, W. F., on the magnetic properties of iron and steel, 455.
Barrow Steelworks, 438.
Barton, Albert Edward, elected member, 5.
Barus, C., on pyrometry, 340.
Barval on mercury in Russian iron ore, 314.
Basic slag, 443.
Bauerman, H., on India as a centre for steel manufacture, 88.
Bauerman, H., on iron ore in the Ural Mountains, 312.
Bauerman, H., on the use of finely divided iron ores, 51.
Bavaria, mineral statistics of, 508.
Beard, J. T., on the ventilation of collieries, 381.
Beilby, G., on by-product ovens, 354.
Beilby, G., on the consumption of coal, 495.
Belgium, blast-furnaces in, 502.
Belgium, mines in, 503.
Belgium, statistics of, 502.
Bell, Sir Lowthian, on a new casting-machine for blast-furnaces, 60.
Bell, Sir Lowthian, on the use of finely divided iron ore, 48.
Bell, Sir Lowthian, vote of thanks by, 237.
Bellet, Daniel, on coal in South Africa, 348.
Bellet, Daniel, on iron ore in Brazil, 323.
Berger on standard tests of cast iron, 468.
Berglöf, A., on American open-hearth steelworks, 437.
Berthelot, Marcellin, on the determination of sulphur in Roumanian petroleum, 493.
Bertrand-Thiel process, 442.
Bessemer process, 438.
Beyer, Peacock & Company, Gorton Foundry, 273.
Bibliography, 530.
Bicycle tubing, testing, 469.
Binckley, George S., on steel head frames, 370.
Blast-furnace, the evolution of the, 408.
Blast-furnace dust, the utilisation of, 405.
Blast-furnace filling apparatus, 400.
Blast-furnace gas, the use of, 401.
Blast-furnace practice, 398.
Blast-furnace slag, 410.
Blast-furnace statistics, 495.
Blast-furnace struck by lightning, 406.
Bloomer, Clifford Edward, elected member, 5.
Blowing-engines, 400.
Bohemia, brown coal in, 499.
Bohemia, ironworks in, 498.
Bosnia and Herzegovina, mineral statistics of, 500.
Boutonnet, G., on underground haulage, 372.
Bowen, M. K., on rails, 471.
Bowser, Howard, obituary notice of, 292.
Boyd, C. R., on coal in Virginia, 350.
Brackley Colliery, the Semet-Solvay coke-ovens at, 290.
Brazil, manganese ore in, 322.
Breda, Louis, elected member, 5.

Brillouin on the theory of deformation of metals, 457.
Britannia Works, 285.
British Columbia, coal in, 346.
British Columbia, iron ore in, 319.
Broms, Gustaf Emil, elected member, 5.
Broms, Otto, elected member, 5.
Broockmann on occluded gases in coal, 341.
Brophy, Michael M., elected member, 5.
Brough, Bennett H., on Brinell's researches, 213.
Brough, Bennett H., on fire-damp in iron ore mines, 331.
Brough, Bennett H., on large forgings, 420.
Brown, A., on the conditions of the iron and steel industries of the United States, 524.
Brown coal in the Rhineland, 345.
Brown, E., on pyrometry, 340.
Brown, H. P., on the corrosion of iron, 473.
Brown, T. Swaffield, on ornamental ironwork, 448.
Brown, W., on the magnetic properties of iron and steel, 455.
Buck, C. R., on electricity in mines, 373.
Bulman, H. F., on coal in Canada, 346.
Bulman, H. F., on coal in New Zealand, 347.
Bulman, H. F., on colonial collieries, 388.
Burrell, H., on the extinction of fire in mines, 383.
Burt, George, elected member, 5.
Busemann, M., on the Southern Ural mining industry, 519.
Büttgenbach, F., on the history of coal-mining, 386, 387.
By-product ovens, 352.

C.

CALCINATION of iron ore, 334.
Caldwell, F. C., on the magnetic properties of iron and steel, 454.
Callendar on pyrometry, 340.
Calorific value, 339.
Calorimetry, 339.
Campbell, E. D., *paper* on "The constitution of steel," 223; alleged non-diffusive power of pure sulphide of iron, 223; Royston's experiments, 225; investigations of the constitution of steel, 226; method employed, 227; results obtained, 228; hypothesis suggested, 229; arguments in favour of the existence of a series of ferro-carbons, 232. *Correspondence:* F. Osmond, 234; C. H. Ridsdale, 236.
Canada, charcoal iron furnace in, 406.
Canada, chrome iron ore in, 320.
Canada, coal in, 345.
Canada, iron ore in, 318.
Canada, iron-smelting in, 504.
Canada, mineral statistics of, 503.
Canada, petroleum in, 361.
Carbide of silicon, the use of, 443.
Carbon, determination of, 482.
Carburisation of malleable iron, 426.
Carpenter, R. C., on the effect of temperature on the strength of iron and steel, 458.
Carrfield and Throstle Bank Mills, Hyde, 273.
Carter, T. L., on mine surveying, 388.
Carter, W. E. H., on coal in Canada, 346.
Caspaar, M., on the iron trade exports and imports of Austria-Hungary, 497.
Casting, a large, 415.
Casting machinery, 405.

Castings, the warping of, 415.
Cast iron pipes, 416.
Castleman, J. W., on iron ore in Alabama, 320.
Cast steel bells, 447.
Catlett, C., on iron ore in Virginia, 321.
Central steam-condensing plant, 424.
Chalmot, G. de, on ferro-silicon, 474.
Charcoal, 352.
Charcoal iron furnace in Canada, 406.
Charcoal used in iron-smelting, 352.
Chatsworth House, 265.
Chemical analysis, 480.
Chemical composition of pig iron, 409.
Chemical properties, 473.
Cherkassov, N., on petroleum in Russia, 360.
Chesneau, G., on explosives and blasting, 376.
Chetham's Hospital and Library, 248.
Childe, H. S., on electricity in mines, 373.
Chrome iron ore in Canada, 320.
Clark, S. S., on the magnetic properties of iron and steel, 453.
Claude, G., on the magnetic properties of iron and steel, 455.
Clayton, W. W., on underground haulage, 372.
Clive, R., on shaft-sinking, 367.
Coal, 341.
Coal and coke prices in Germany, 508.
Coal, the analysis of, 492.
Coal, consumption of, 495.
Coal-cutting machinery, 374.
Coal in Algeria, 350.
Coal in Asia Minor, 350.
Coal in Austrian Silesia, 343.
Coal in British Columbia, 346.
Coal in Canada, 345.
Coal in Colorado, 348.
Coal in Donetz basin, 345.
Coal in France, 345.
Coal in Hungary, 344.
Coal in Ireland, 342.
Coal in Kent, 342.
Coal in Lower Austria, 343.
Coal in Michigan, 348.
Coal in New South Wales, 346.
Coal in New Zealand, 347.
Coal in North Staffordshire, 341.
Coal in Porto Rico, 350.
Coal in Servia, 344.
Coal in South Africa, 347.
Coal in Sumatra, 351.
Coal in Upper Silesia, 345.
Coal in Virginia, 350.
Coal industry of Russia, 519.
Coal-mining, 366.
Coal-mining, the history of, 385.
Coal screening and washing, 392.
Coal, tests of, 339.
Coal-washing, 392.

Coke, 352.
Coking of Indian coal, 357.
Coke-oven plant near Dombrau, 355.
Coke-ovens at the Wharncliffe Silkstone Colliery, 254.
Colby, A. L., on metallurgical analysis, 480.
Cold process galvanisation, 449.
Coldwell-Horsfall, Henry Herbert, elected member, 5.
Collieries in Great Britain, 388.
Collieries, the lighting of, 384.
Collieries, rescue appliances for, 384.
Collieries, the ventilation of, 381.
Colonial collieries, 388.
Colorado, coal in, 348.
Colorado, natural gas in, 364.
Colorado, petroleum in, 361.
Combined Bessemer and puddling process, 443.
Comparative tables, 525.
Compressed air tools, 420.
Conditions of the iron and steel industries of the United States, 524.
Constitution of steel, 223.
Cook, E. S., on casting machinery, 406.
Cook, E. S., on slips and explosions in the blast-furnace, 398.
Cooper, Joseph, on a new casting-machine for blast-furnaces, 61.
Coppée, E., on by-product ovens, 352.
Corrosion of iron, 473.
Cousins, W. J., on deep boring, 366.
Cowper-Coles, S., on the cold process galvanisation, 449.
Craven Brothers Limited, 276.
Crewe Works, 267.
Crobaugh, F. L., on the determination of silicon, 484.
Crobaugh, F. L., on the determination of sulphur, 486.
Cronemeyer, W. C., on iron ore in British Columbia, 319.
Cronemeyer, W. C., on the manufacture of tin plates, 449.
Cronquist, W., on the preliminary examination of fireclays, 338.
Crucible steel, 426.

D.

DAMASK steel, 445.
Damping down blast-furnaces, 398.
Daniel, J., on radiographic examination of steel plates, 465.
Davies, Herbert E., on the action of water on galvanised iron, 474.
Davies, John C., elected member, 5.
Davis, G. C., on malleable castings, 415.
Davison, James, on pumping plant, 330.
Dawkins, Boyd, on coal in Kent, 342.
Dawson, Robert, elected member, 5.
Day, David T., on iron ore in the Antilles, 321.
Day, W. C., on the origin of petroleum, 358.
Deccan, iron industry of, 65.
Deep boring, 366.
Dehnke, H., on the ventilation of collieries, 382.
Dellwik-Gröndal separator, 35.
Dellwik gas-producer, 365.
Demaret, Léon, on iron ore deposits, 307.
Demeure, A., on shaft-sinking, 367.
Desvignes on electricity in mines, 373.

Deutscher Kaiser ironworks, 406.
Diamond boreholes, 327.
Dicke, H., on the Dellwik gas-producer, 365.
Dietz, E., on the iron ore mines of Rar-el-Maden, 324.
Direct reduction of pulverulent ores, 16.
Dixon, W., on the condition of the iron and steel industries of the United States, 524.
Doherty, W. M., on manganese ore in Australia, 318.
Domenech, M. V., on coal in Porto Rico, 350.
Donald, David Patrick, elected member, 5.
Donald, J. T., on chrome iron ore in Canada, 320.
Donkin, Bryan, on calorimetry, 339.
Dopp, on petroleum motors, 362.
Dorsey, H. G., on the magnetic properties of iron and steel, 457.
Dougherty, G. T., on the determination of carbon, 483.
Douglas, James, elected member, 5.
Douglas, James, on charcoal used in iron-smelting, 352.
Douglas, James, on gas-producers, 365.
Douglas, James, on iron-smelting in Canada, 504.
Douglas, James, on Swedish iron metallurgy and its application to Canada, 522.
Dubbel, H., on mine drainage, 380.
Duboin, on aluminium as a reducing and heating agent, 476.
Dumas, L., on the magnetic properties of iron and steel, 453.
Dumont, E., on the magnetic properties of iron and steel, 453.
Dunn, E. J., on coal in South Africa, 347.
Dunstan, W. R., on the rusting of iron, 473.
Durfee, William Franklin, obituary notice of, 292.

E.

Earliest production of coke, 357.
Economics of coal-mining, 388.
Ede, J. A., on American collieries, 392.
Effect of lime and magnesia on sulphur in the blast-furnace, 411.
Effect of punching and shearing, 465.
Effect of temperature on the strength of iron and steel, 458.
Ehrhardt, L., on new rolling-mill engines, 423.
Elba, iron ore in, 514.
Elbers, A. D., on the utilisation of slag, 410.
Election of new members, 5.
Electricity in mines, 372.
Electric power in rolling-mills, 423.
Electric rock-drills, 330.
Electric smelting of iron and steel, 434.
Electric transmission of power, 330.
Electric welding, 445.
Enamelled iron ware, 450.
*Engineering News*, editor of, on the use of finely divided iron ore, 50.
Engineering works of the Lancashire and Yorkshire Railway Company, 254.
Eolotropy in steel, 466.
Epton, W. M., on mine drainage, 379.
Etheridge, R., on coal in Kent, 342.
Evans, A. W., on handling coal, 396.
Evans, John, elected member, 6.
Evelyn, John, on the earliest production of coke, 357.
Everett, S. A., on steel head-frames, 370.

Evolution of the blast-furnace, 408.
Explosives and blasting, 376.
Extinction of fire in mines, 383.

F.

Fairbanks, Harold W., on petroleum in California, 361.
Farrar, William, elected member, 6.
Fawcett, W., on handling coal, 396.
Fawcett, W., on mining in the Lake Superior district, 327.
Ferro-silicon, 474.
Filiti, G., on the determination of sulphur in Roumanian petroleum, 492.
Fillunger, A., on Austrian collieries, 389.
Fillunger, A., on coal screening and washing, 393.
Fine coal, the utilisation of, 393.
Finely divided iron ore, 8.
Fire-damp detection, 383.
Fire-damp in iron ore mines, 331.
Fire-damp outbursts, 382.
Flagg, Stanley Griswold, jun., elected member, 6.
Flather, David, elected member, 6.
Fleming, Professor, on the magnetic properties of iron and steel, 455.
Foniakoff, A., on the manganiferous pig iron industry of Russia, 518.
Foote, W. M., on recent researches on meteorites, 326.
Forge and mill machinery, 420.
Forging wrought iron axles, 446.
Foster, C. Le Neve, on electric rock-drills, 330.
Foster, O. R., on the effect of lime and magnesia on sulphur in the blast-furnace, 411.
Foster, William Orme, obituary notice of, 293.
Foundry practice, 411.
France, blast-furnaces in, 504.
France, coal in, 345.
France, iron ore in, 309.
France, iron trade statistics of, 504.
Frank on the improvements in producer gas, 365.
Fraser, W. A., on natural gas at Athabasca Landing, 364.
Freakley, W., on winding appliances, 369.
Fremont, C., on the effect of punching and shearing, 465.
Frew, John, obituary notice of, 293.
Fritz, J., on rolling-mill fly-wheels, 422.
Froitzheim, E., on the use of coke for boiler-firing, 357.
Fuchs, P., on fire-damp detection, 383.
Fuchs, P., on the ventilation of collieries, 381.
Fuel, 339.
Fuel analysis, 492.
Furniss, J. W., on iron ore in Brazil, 323.
Further treatment of iron and steel, 445.

G.

Gaebler, C., on coal in Upper Silesia, 345.
Galloway, W., on methods of working coal, 377.
Galloway, W., on shaft-sinking, 367.
Galloway, W., on the South Wales coalfield, 342.
Galloway, W., on the ventilation of collieries, 382.

Galloway, W., on winding appliances, 369.
Galloways, Limited, 261.
Gamble, Arnold, elected member, 6.
Gardner, Harry N., on the utilisation of fine coal, 396.
Gas analysis, 493.
Gas from wood, 352.
Gas-producers, 365.
Gauthier, on aluminium as a reducing and heating agent, 476.
Gerand on mine drainage, 381.
Gerard, A., on the electric smelting of iron and steel, 434.
Germany, imports and exports of, 505.
Gerrard, J., on fire-damp outbursts, 382.
Ghysen on winding ropes, 371.
Gibson, Walcot, on coal in North Staffordshire, 341.
Giorgis, Giovanni, on the determination of nickel, 488.
Gjers, L., on hot blast, 400.
Glasenapp, M., on the iron ore deposits near Kertsch, 312.
Glazier, Richard, on ornamental ironwork, 448.
Goichot, on electricity in mines, 373.
Goldschmidt, H., on aluminium as a reducing and heating agent, 475.
Gordon, F. W., on blowing-engines, 400.
Goupillière, H. de la, on methods of working coal, 377.
Graphite, 337.
Gray, T., on eolotropy in steel, 466.
Great Britain, collieries in, 388.
Greece, mineral statistics of, 510.
Greiner, A., on practical microscopic analysis, 149.
Greiner, A., vote of thanks by, 238.
Gresley Ironworks, Salford, 276.
Greven, F., on manganese ore in Brazil, 322.
Groll, Friedrich, on the determination of iron, 490.
Guillaume, C. E., on the alloys of iron and nickel, 465.

H.

HADDON HALL, 265.
Hadfield, R. A., on alloys of iron and nickel, 462.
Hadfield, R. A., on a new casting-machine for blast-furnaces, 63.
Hadfield, R. A., on crucible steel, 426.
Hadfield, R. A., on the effect of temperature on the strength of iron and steel, 460.
Hadfield, R. A., on the structure of steel and its thermal and mechanical treatment, 209.
Hadfield, R. A., on the solution theory of carburised iron, 181.
Haedicke on compressed air tools, 420.
Hanappe, S., on the ventilation of collieries, 381.
Handling coal, 396.
Hanisch, V., on coal in Lower Austria, 343.
Hann, E. M., on mine drainage, 379.
Harbord, F. W., on practical microscopic analysis, 151.
Hardie, W. D. L., on coal-cutting machinery, 374.
Harland, R. H., on iron ore in Kent, 308.
Harpf, A., on Austrian crucible steelworks, 432.
Harrison, J. H., on hot blast, 400.
Hartman, J. M., on slips and explosions in the blast-furnace, 398.
Harzé, E., on the mineral statistics of Belgium, 502.
Haskovec, A., on Moravian fireclay, 337.
Hatt, W. K., on the tests of steel, 469.

Havard-Duclos, on methods of working coal, 377.
Hawdon, William, on casting machinery, 405.
Hawdon, William, on a new casting-machine for blast-furnaces, 59.
Haworth, R., & Company, Limited, 263.
Hedley, J. L., on fire-damp in iron ore mines, 331.
Hegner, E., on coal in Servia, 344.
Heise on electricity in mines, 373.
Heise on explosives and blasting, 377.
Heller, on the alloys of iron and nickel, 465.
Henderson, G. R., on wheels, 470.
Hersten, J., on underground haulage, 372.
Herting, O., on the determination of sulphur, 484.
Herz, E., on modern foundry practice, 414.
Heyn, E., on the texture of iron, 451.
Hildburgh, W. L., on mining in the Lake Superior district, 327.
Hill, J. W., on the tests of coal, 339.
Hille, F., on electric rock-drills, 330.
Hills, R. C., on coal in Colorado, 348.
History of iron, 417.
Hodbarrow mines, 326.
Hodgson, Henry, elected member, 6.
Höfer, H., on the age of iron ore veins, 306.
Hoffmann, L., on iron ore in Luxemburg and Lorraine, 310.
Holmes, C., on coal in Michigan, 348.
Hot blast, 400.
Howe, H. M., on the Bertrand-Thiel process, 442.
Howe, H. M., on metallurgical education, 524.
Howe, H. M., on the structure of steel and its thermal and mechanical treatment, 215.
Hubon, E., on the electric smelting of iron and steel, 434.
Hulse & Company, 278.
Hulst, N. P., on mining in the Lake Superior district, 327.
Humphreys-Davies, George, on the economics of coal-mining, 388.
Hungarian mineral statistics, 500.
Hungary, coal in, 344.
Hyderabad, iron industry of, 65.

I.

IMPROVEMENT in producer gas, 365.
Improving open-hearth steel, 434.
India as a centre for steel manufacture, 83.
India, iron manufacture in, 512.
India, production of coal in, 511.
Indiana, natural gas in, 364.
Internal strains in steel, 466.
Ireland, coal in, 342.
Iron alloys, 461.
Iron and steel, analysis of, 480.
Iron, determination of, 482, 489.
Iron industry of the Hyderabad Deccan, 65.
Iron ore, the analysis of, 489.
Iron ore deposits, 307.
Iron ore deposits near Kertsch, 312.
Iron ore deposits of Pazzano, 311.
Iron ore in Alabama, 320.

Iron ore in British Columbia, 319.
Iron ore in the Antilles, 321.
Iron ore in Belle Isle, Newfoundland, 320.
Iron ore in Cape Breton, 319.
Iron ore in France, 309.
Iron ore in Kent, 308.
Iron ore in Luxemburg and Lorraine, 310.
Iron ore in Siegen, 311.
Iron ore in Spain, 314.
Iron ore in Sweden, 315.
Iron ore in Switzerland, 317.
Iron ore in Tunis, 324.
Iron ore in the Ural Mountains, 311.
Iron ore in Virginia, 321.
Iron ore mines of Rar-el-Maden, 323.
Iron ore mining, 326.
Iron ores, 306.
Italy, mineral statistics of, 514.

J.

JACKSON, J. P., on electricity in mines, 372.
Jacobson, C. A., on manganese in the finery process, 417.
Jacoupy on the use of blast-furnace gas, 401.
Japanese steelworks, 440.
Japan, petroleum in, 361.
Jeans, J. S., on the world's consumption of pig iron, 527.
Jencke on coal and coke, 508.
Jewett on modern foundry practice, 414.
Jicinsky on Austrian collieries, 390.
Jicinsky on coal screening and washing, 393.
Jicinsky on coke-oven plant near Dombrau, 355.
Johnson, G., on the economics of coal-mining, 388.
Johnson, G., on handling coal, 396.
Johnston, E. E., on standards for iron analysis, 481.
Johnston, William Joseph, elected member, 6.
Jones, James, elected member, 6.
Jorissem, A., on the rare elements in Liége coal, 344.
Josse on the workshop at the Charlottenburg Technical High School, 450.
Jüptner, Baron H. von, on the solution theory of carburised iron, 185.

K.

KARLIK, J., on registering speed of blowing-engines, 442.
Kaufmann, L., on the utilisation of fine coal, 394.
Keep, W. J., on new American foundries, 414.
Kellett, W., on the washing of Furness ore, 332.
Kemp, J. F., on titaniferous magnetites, 307.
Kendall & Gent's Works, 264.
Kennedy, William, obituary notice of, 294.
Kennedy, W., on a blast-furnace filling apparatus, 400.
Kent, coal in, 342.
Kent, iron ore in, 308.
Kerr, George L., on mine drainage, 380.

Kestranek, William, elected member, 6.
Kette on the ventilation of collieries, 382.
Khudintzov, Captain, on coal in the Donetz basin, 345.
Kiesselbach, C., on new rolling-mill engines, 422, 423.
Kirkland, J. W., on underground haulage, 372.
Kirtland, A. P., on coal in Pennsylvania, 349.
Kissling, R., on the world's output of petroleum, 528.
Klein, Jacob, elected member, 6.
Koehler, G., on iron ore in Siegen, 311.
Koerte, C., on coal-cutting machinery, 374.
Körting, J., on petroleum motors, 362.
Körting, J., on the use of blast-furnace gas, 405.
Kosakevitz, P., on the use of petroleum for the manufacture of sheet iron, 362.
Kovar, F., on Moravian fireclay, 337.
Kraft ironworks near Stettin, 407.
Kretschner, Frank, on Devonian iron ores in Moravia, 309.
Krupp's works, 508.
Kupelwieser, F., on aluminium as a reducing and heating agent, 475.

L.

LACROIX, A., on iron ore in France, 309.
Lafitte on the lighting of collieries, 384.
Lakes, Arthur, on coal in Colorado, 348.
Lakes, Arthur, on mine timber, 330.
Lakes, Arthur, on natural gas in Colorado, 364.
Lakes, Arthur, on petroleum in Colorado, 361.
Lancaster, Charles, on the iron trade statistics of the United Kingdom, 495.
Lane, H. M., on diamond boreholes, 327.
Lange, E. F., on the relation of steel, its thermal and mechanical treatment, 213.
Lang, O., on iron ore in Luxemburg and Lorraine, 311.
Lapsley, Gaillard T., on the history of iron, 417.
Large forging presses, 420.
Large forgings, 420.
Lebeau, P., on ferro-silicon, 475.
Le Chatelier, H., on the effect of temperature on the strength of iron and steel, 459.
Le Chatelier, H., on the magnetic properties of iron and steel, 457.
Le Chatelier, H., on practical microscopic analysis, 157.
Leck, W., on fire-damp in iron ore mines, 331.
Ledebur, A., on improving open-hearth steel, 434.
Ledebur, A., on modern foundry practice, 411.
Ledebur, A., on science and iron-smelting, 477.
Ledebur, A., on standard tests of cast iron, 467.
Ledyard, T. D., on iron ore in Canada, 318.
Ledy on the action of sea-water on iron, 474.
Lees, Asa, & Company, Limited, 279.
Lencauchez, A., on gas-producers, 365.
Lencauchez, A., on the open-hearth plant at Hayange, 437.
Lester, Isaac E., elected member, 6.
Lighting of collieries, 384.
Linck, Gottlob E., on recent researches on meteorites, 325.
Lintern, William Turner, elected member, 6.
Liquid fuel, 358.
Lisboa, Ribeiro, on manganese ore in Brazil, 322.

Little, G., on handling coal, 396.
Lombardy, the iron industry of, 515.
Lord Mayor of Manchester, welcome by, 1.
Lorraine, iron ore in, 310.
Louis, D. A., on iron ore in Sweden, 315.
Louis, H., on the ventilation of collieries, 381.
Lucchesi, E., on the determination of sulphur in coal, 492.
Lueg, C., on German imports and exports, 506.
Lürmann, F. W., on the use of blast-furnace gas, 401.
Luxemburg, iron ore in, 310.
Luxemburg, mineral statistics of, 510.

M.

M'Farlane, G. C., on diamond boreholes, 328.
Macfarlane, John, elected member, 6.
Mackay, Alexander, on coal in New Zealand, 347.
M'Murtrie, G. E. J., on mine drainage, 380,
McNeill, H. C., *paper* on "Some forms of magnetic separators, and their application to different ores," 18; 1. The Wenström machine, 19; 2. The Monarch separator, 30; 3. The Dellwik-Gröndal separator, 35; 4. The Heberle separator, 38; 5. The Wetherill machine, 43.—*Discussion:* J. Riley, 45; G. J. Snelus, 46; Sir L. Bell, 48; J. E. Stead, 49.—*Correspondence:* Editor *Engineering News*, 50; H. Bauerman, 51.
Macpherson, M. A., on the iron ore in Cape Breton, 319.
McWilliam, A., on the solution theory of carburised iron, 191.
Magnesite, 337.
Magnetic concentration of iron ore, 332.
Magnetic iron ores in Eastern Ontario, 318.
Magnetic properties of iron and steel, 453.
Magnetic separators, 18.
Maguire, Don, on coal in Utah, 349.
Mahon, R. H., on charcoal used in iron-smelting, 352.
Mahon, R. H., on the coking of Indian coal, 357.
Mahon, R. H., on the iron manufacture in India, 512.
Mahon, R. H., *paper* on "India as a centre for steel manufacture," 83; consumption of manufactured steel in India, 83; coal output, 84; iron ore, 84; freight, 85; labour question, 86.—*Discussion:* H. Bauerman, 88; R. Price-Williams, 88.—*Correspondence:* C. von Schwarz, 89; H. G. Turner, 99.
Main, James A., elected member, 6.
Malleable castings, 415.
Manchester Cathedral, 247.
Manchester Corporation cold stores, 282.
Manchester Corporation foreign animals wharf, 282.
Manchester Corporation gasworks, 280.
Manchester Corn, Grocery, and Produce Exchange, 247.
Manchester Corporation hydraulic power supply pumping station, 283.
Manchester Corporation abbatoirs, 281.
Manchester Crematorium, 284.
Manchester Meeting, 1.
Manchester Municipal Technical School, 283.
Manchester Ship Canal, 256.
Manchester Town Hall, 246.
Manganese in the finery process, 417.
Manganese ore in Brazil, 322.

Manganese ore in South Russia, 313.
Manganiferous pig iron industry of Russia, 518.
Manufacture of propeller shafts, 446.
Marschick on iron alloys, 462.
Martens, A., on tests of wire rope, 470.
Martinet, M., on coal in France, 345.
Martinet on winding appliances, 369.
Martin, H. W., on winding appliances, 367.
Massie, G. J., on the ventilation of collieries, 382.
Mauerhofer, J., on iron ore in Sweden, 315.
Mauerhofer, J., on the production of coal in Sweden, 522.
Maurice on the analysis of coal, 492.
Mayer, J., on rescue appliances for collieries, 384.
May, G. J., on colonial collieries, 389.
May, Walter J., on modern foundry practice, 413.
Mechanical preparation, 332.
Meineke, C., on the determination of sulphuric acid, 490.
Meissner, C. A., on iron ore in Belle Isle, Newfoundland, 320.
Mercury in Russian iron ore, 314.
Merriman, M., on testing machines, 467.
Merritt, E., on the magnetic properties of iron and steel, 455.
Metallurgical analysis, 480.
Metallurgical education, 524.
Metallurgical preparation, 334.
Meteorites, recent researches on, 324.
Meunier, S., on recent researches on meteorites, 324.
Meyer, E., on the use of blast-furnace gas, 404.
Meyer, G. A., on rescue appliances for collieries, 385.
Meyers, H. K., on underground haulage, 371.
Michell, Stephen, on mine drainage, 378.
Michigan, coal in, 348.
Michigan, iron ore in, 524.
Micro-organisms of coal, 351.
Microscopic analysis, 102.
Microstructure of iron, 451.
Miller, H. W., on winding appliances, 369.
Miller, James Williard, *paper* on "Pig iron fractures and their value in foundry practice," 160; origin of the present method of grading pig iron, 160; quotation from Dud Dudley, 161; grades established in Alabama, 161; confusion owing to grading by the fracture, 162; chemical composition the only true guide, 165; necessity for superseding method of casting in sand beds, 166. Conclusion, 168.
Milne, Isaac Bernard, elected member, 6.
Mine drainage, 377.
Mine surveying, 387.
Mine timber, 330.
Mineral statistics of Belgium, 502.
Mineral statistics of the United Kingdom, 494.
Mining in the Lake Superior district, 327.
Mixter, W. G., on the ventilation of collieries, 382.
Modern foundry practice, 411.
Moldenke, B., on transverse tests of cast iron, 468.
Molterski, K., on the determination of oxygen, 493.
Moore on the warping of castings, 415.
Moran, M. A., on casting machinery, 406.
Moravia, Devonian iron ores in, 308.
Moravian fireclay, 337.

Mordey, W. M., elected member, 6.
Moreau, G., on torsion and recalescence of steel, 466.
Morgans, John T., elected member, 6.
Morgans, W., on winding engines, 328.
Morgenroth, L. C., on winding appliances, 369.
Morgenroth, W. C., on the extinction of fires in mines, 383.
Morison, D. B., on the manufacture of propeller shafts, 446.
Mortier on the use of blast-furnace gas, 401.
Mott, A. C., on moulding, 416.
Moulding, 416.
Moxham, A. T., on rails, 470.
Murgue, D., on the ventilation of collieries, 381.
Musgrave, John, & Sons, Limited, 286.

N.

Nangle, J., on ornamental ironwork, 449.
Natural gas, 364.
Needham, John, obituary notice of, 294.
New American foundries, 414.
New casting machine for blast-furnaces, 53.
New East River suspension bridge, 448.
New rolling-mill engines, 422.
New South Wales, coal in, 346.
New South Wales, mineral statistics of, 496.
New Zealand, coal in, 347.
Nickel, the determination of, 487.
Niessen, Dr., on brown coal in the Rhineland, 345.
Nitze, H. B. C., on iron ore in the Ural Mountains, 311.
Norris, Charles Guest, elected member, 6.
Norton, C. L., on calorimetry, 339.
Norton, J. T., on the determination of iron, 489.
Notes on works and places visited, 254.
Nowell, W., on electricity in mines, 373.
Nowlan, John, elected member, 6.
Nursey, Perry F., vote of thanks by, 238.

O.

Obituary, 292.
Occluded gases in coal, 341.
O'Donahue, T. A., on winding appliances, 368.
Oldham, H. G. V., on central steam condensing plant, 425.
Ontario, natural gas in, 364.
Open-hearth furnaces at Barrow, 437.
Open-hearth plant at Hayange, 437.
Open-hearth process, 434.
Origin of petroleum, 358.
Ornamental ironwork, 448.
Orsman, W. J., on explosives and blasting, 376.
O'Shea, L. T., on explosives and blasting, 376.
Osmond, F., on the constitution of steel, 234.
Osmond, F., on the effect of temperature on the strength of iron and steel, 458.

Osmond, F., on the thermal treatment of steel, 217.
Oxfordshire, iron ore in, 308.
Oxygen, determination of, 493.
Owen, Thomas, elected member, 6.
Owens College, 252.
Ozokerite in Austria, production of, 500.

P.

PARDEE, F., on the extinction of fire in mines, 383.
Parker, B., on coal-cutting machinery, 374.
Parker, E. W., on by-product ovens, 354.
Parker, E. W., on coal-cutting machinery, 374.
Parker, E. W., on the coke production of the United States, 524.
Parry, J., on the physical analysis of steel, 451.
Pasquier, P., on the manufacture of tin plates, 450.
Pattern-making, 416.
Paul on explosives and blasting, 376.
Paul, F. W., on the relation between the structure of steel, its thermal and mechanical treatment, 211.
Paweck, H., on metallurgical analysis,.480.
Pazzano iron ore deposits, 311.
Pearn, Frank, & Company, Limited, 287.
Peat briquettes, 397.
Peat charcoal, 352.
Peel Park, Royal Museum and Libraries, Salford, 249.
Pennock, J. D., on by-product ovens, 353.
Pennsylvania, coal in, 349.
Percy, T. M., appointed scrutineer, 5.
Persistency of Swedish iron ore deposits, 315.
Petermann, on peat charcoal, 352.
Peters, Samuel, on the combined Bessemer and puddling process, 443.
Peters, Samuel, on the history of iron, 418.
Petersson, W., on iron ore deposits, 307.
Petit on mine drainage, 381.
Petit on winding appliances, 370.
Petley, William, elected member, 6.
Petroleum and its flashing point, 362.
Petroleum in Austria, production of, 500.
Petroleum in California, 361.
Petroleum in Canada, 361.
Petroleum in Colorado, 361.
Petroleum in Roumania, 360.
Petroleum in Russia, 359.
Petroleum motors, 362.
Petroleum, the origin of, 358.
Pfankuch, C., on the electric transmission of power, 330.
Phosphoric acid in basic slag, determination of, 491.
Physical analysis of steel, 451.
Physical properties of iron and steel, 451.
Pig iron fractures and their value in foundry practice, 160.
Pine Mill Company, Limited, Oldham, 261.
Platt, John, elected member, 6.
Platt, S. R., vote of thanks by, 238.
Platt, S. R., welcome of Institute to Manchester, 2.

Platt Brothers & Company, Limited, Oldham, 256.
Poech, F., on the mineral statistics of Bosnia and Herzegovina, 501.
Poech, F., on the Zenica and Kreka collieries, Bosnia, 390.
Pope, F. J., on the determination of titanium and vanadium, 489.
Pope, F. J., on the magnetic iron ores in Eastern Ontario, 318.
Poppe, J., on coal in Austrian Silesia, 343.
Porter, John Bonsall, elected member, 6.
Porter, John Bonsall, on practical microscopic analysis, 154.
Porter, R. P., on iron ore in the Antilles, 321.
Poulaine, Eugène, elected member, 7.
Powdered ore in the open-hearth furnace, 15.
Pradel, Colomb, on the utilisation of blast-furnace dust, 405.
Preliminary examination of fireclays, 338.
Prenger, H., on the Kraft Ironworks, 407.
President on Brinell's researches, 212.
President on practical microscopic analysis, 148, 154.
President on the solution theory of carburised iron, 180.
President on the use of finely divided iron ore, 51.
President, vote of thanks to Lord Mayor and Reception Committee, 2.
President, vote of thanks by, 236, 239.
Preus, Nordal, on the iron ore of Spain, 314.
Price-Williams, R., on India as a centre for steel manufacture, 88.
Priwoznik, E., on petroleum and its flashing point, 362.
Production of malleable iron, 417.
Production of pig iron, 398.
Production of steel, 426.
Prost, A., on iron ore in Tunis, 324.
Prussia, mineral statistics of, 506.
Prytherch, H. O., on American collieries, 392.
Public buildings and institutions visited at the Manchester Meeting, 246.
Pumping plant, 330.
Pyrometry, 340.

Q.

QUIVY, L., on the cold process galvanisation, 449.

R.

RADIOGRAPHIC examination of steel plates, 465.
Rails, 470.
Railway waggons, 447.
Randolph, Beverley S., on coal in Pennsylvania, 349.
Rare elements in Liége coal, 344.
Rasch, on the tests of steel, 469.
Rateau, A., on the ventilation of collieries, 381.
Redaelli, Pietro, elected member, 7.
Redlich, K., on coal in Hungary, 344.
Redlich, K. A., on petroleum in Roumania, 360.
Refractory materials, 337.
Registering speed of blowing-engines, 442.
Relation between the structure of steel and its thermal and mechanical treatment, 195.
Renault, B., on the micro-organisms of coal, 351.
Rescue appliances for collieries, 384.
Retiring Members of Council, 5.
Rhoads, E., on the magnetic properties of iron and steel, 453.

Rice, George D., on mine drainage, 379.
Richards, E. Windsor, on a new casting machine for blast-furnaces, 58.
Richards, F. B., on slips and explosions in the blast-furnace, 398.
Richardson, J. M., on pattern-making, 416.
Ridley, Alfred Forbes, elected member, 7.
Ridsdale, C. H., on the constitution of steel, 236.
Ridsdale, C. H., on the structure of steel and its thermal and mechanical treatment, 208.
Ridsdale, C. H., *paper* on "Practical microscopic analysis for use in the steel industries, with an introduction to a systematic study of soft and dead soft steel," 102; Section I. Introductory remarks, 102; reason for bringing subject forward, 102; our experience, 103; directions of probable usefulness and conditions to be met, 104; reasons for dealing with soft steel, 105; exactions of consumers of soft steel, 105; collection and verification of data necessary, 106; some of the points previously verified, 107; outline of scheme adopted for the study, 108.—Section II. Procedure, 110; classification, 110; soft, 110; size of grain, 113; system of examination, 115.—Section III. Results obtained, 116; leading features of Classes I. to V., 116; index to the main practical points touched on, 126.—Appendix I. Sampling, 131; grinding, 132; mounting, protecting, and etching, 133; illumination and examination, 134; photographing, 135.—Appendix II., 138 147.—*Discussion:* The President, 148; A. Greiner, 149; F. W. Harbord, 151; J. E. Stead, 151; J. B. Porter, 154; C. H. Ridsdale, 155, 158.—*Correspondence:* H. Le Chatelier, 157.
Riedler, A., on mine drainage, 378.
Riedler, A., on blowing-engines, 401.
Riley, E., on coal in Sumatra, 351.
Riley, E., on iron ore in Kent, 308.
Riley, James, on the use of finely divided iron ore, 45.
Roberts-Austen, Sir William C., on iron alloys, 461.
Roberts-Austen, Sir William C. *See* also President.
Robinson, Thomas, & Son, Limited, 287.
Rodde on winding ropes, 371.
Rod-rolling, 420.
Rollin, Francis Thomas, elected member, 7.
Rolling-mill fly-wheels, 422.
Rolling rails, 422.
Ronaldson, J. H., on the coal in New South Wales, 346.
Rössner on rescue appliances for collieries, 385.
Rothwell, R. P., on metallurgical education, 525.
Rouff, V., on the determination of iron, 482.
Roumanian petroleum, determination of sulphur in, 492.
Royal Exchange, Manchester, 247.
Royal Ironworks, Messrs. Vaughan & Son, 291.
Royal Technical Institute, Peel Park, Salford, 251.
Roy, Andrew, on coal in Virginia, 350.
Russell, S. Bent, on standard tests of cast iron, 468.
Russia, the iron industry of, 516.
Russia, petroleum in, 359.
Russner, J., on the effect of temperature on the strength of iron and steel, 458.
Rusting of iron, 473.

S.

SALFORD Corporation gasworks, 288.
Sandberg, A. O. F., elected member, 7.
Sandford, William, elected member, 7.

Sanitation in collieries, 385.
Sargent, George W., on the determination of nickel, 487.
Sattmann, A., on improving open-hearth steel, 435.
Sauveur, Albert, on the microstructure of iron, 451.
Sauveur, Albert, *paper* on "The relation between the structure of steel and its thermal and mechanical treatment," 195: I. Changes of structure brought about by heat treatment, 195; II. Changes of structure brought about by work, 197; III. Conclusions, 199.—Appendix I., 203; Appendix II., 205; Appendix III., 206.—*Discussion:* C. H. Ridsdale, 208; R. A. Hadfield, 209; F. W. Paul, 211; the President, 212; B. H. Brough, 213; E. F. Lange, 213.—*Correspondence:* H. M. Howe, 215; F. Osmond, 217; J. E. Stead, 219.
Schaffer, F., on coal in Hungary, 344.
Schindler on improving open-hearth steel, 437.
Schliemann on coke-oven plant near Dombrau, 355.
Schneider, R., on coal and coke in Germany, 509.
Schniewind, F., on the use of coke-oven gas for illuminating purposes, 356.
Schotte, A., on new American foundries, 414.
Schraml, C., on electric rock-drills, 330.
Schröder, K., on the determination of iron, 489.
Schulte, F., on shaft sinking, 367.
Schultz, G., on by-product ovens, 353.
Schwarz, Cecil von, on coal in Algeria, 350.
Schwarz, Cecil von, on the iron industry in the territory of His Highness the Nyzam of Hyderabad, 89.
Schweder, K., on the ventilation of collieries, 382.
Science and iron-smelting, 477.
Scott, Charles, elected member, 7.
Scott, E. Kilburn, on coal-cutting machinery, 375.
Scott, Eva, on the history of iron, 418.
Scott, Frederick George, elected member, 7.
Seamless tubes, 447.
Serres, De, on shaft sinking, 367.
Servia, coal in, 344.
Shaft sinking, 367.
Shimer, P. W., on the determination of carbon, 483.
Ship construction, 495.
Siegen, iron ore in, 311.
Silicon and carbon in cast iron, 409.
Silicon, determination of, 484.
Simon, Henry, obituary notice of, 295.
Sjögren, H., on the persistency of Swedish iron ore deposits, 315.
Sjostedt, E. A., on Swedish iron metallurgy and its application to Canada, 522.
Slabbing-mill, 422.
Sladeček, R., on the Zenika and Kreka collieries, Bosnia, 391.
Slag ladles, 401.
Slag, the utilisation of, 410.
Slips and explosions in the blast-furnace, 398.
Smith, A. W., on standards for iron analysis, 481.
Smith, K. M., on the extinction of fire in mines, 383.
Smith, O., on testing bicycle tubing, 469.
Smith, William, elected member, 7.
Snelus, G. J., on the solution theory of carburised iron, 180.
Snelus, G. J., on the use of finely divided iron ore, 46.
Snelus, G. J., jun., elected member, 7.
Soho Ironworks, Bolton, 277.
Solution theory of carburised iron, 160.

South Africa, coal in, 347.
South Chicago Bessemer works, 439.
Southern Ural mining industry, 519.
South Russia, manganese ores in, 313.
South Wales coalfield, 342.
Spain, imports and exports of, 520.
Spain, iron ore in, 314.
Spain, iron trade statistics of, 520.
Spée, Théo, on mines in Belgium, 503.
Spencer, G., on the extinction of fire in mines, 384.
Spüller, J., on the determination of carbon, 482.
Standards for iron analysis, 480.
Standard tests of cast iron, 467.
Stansfield, Alfred, elected member, 7.
Stansfield, Alfred, *paper* on "The present position of the solution theory of carburised iron," 169; introduction, 169; the solidification of carburised iron, 170; formation of carbide of iron, 174; formation of graphite, 175; the allotropic changes of iron and their influence on the solid solutions of iron and cementite, 176.—*Discussion:* The President, 180; G. J. Snelus, 180; R. A. Hadfield, 181; J. E. Stead, 182.—*Correspondence:* Baron Jüptner, 185; A. McWilliam, 191.
Statistics, 494.
Stead, J. E., on practical microscopic analysis, 151.
Stead, J. E., on the relation between the structure of steel, its thermal and mechanical treatment, 219.
Stead, J. E., on the solution theory of carburised iron, 182.
Stead, J. E., on some forms of magnetic separators, 49.
Stead, J. E., on the use of finely divided iron ore, 49.
Steel dam for a reservoir, 448.
Steel head-frames, 370.
Steel manufacture, India as a centre for, 83.
Steel, tests of, 469.
Steinbart pyrometer, 341.
Stens on the ventilation of collieries, 381.
Steuer, S., on mine drainage, 380.
Stevens, J. S., on the magnetic properties of iron and steel, 457.
Stirling, James, on the world's supply of iron ore and pig iron, 527.
Stockport gas-engine works, Reddish, 272.
Stupakoff, S. H., on new American foundries, 415.
Sulphur, determination of, 484.
Sulphur in coal, the determination of, 492.
Sulphuric acid, determination of, 490.
Sumatra, coal in, 351.
Summers, B. S., on silicon and carbon in cast iron, 409.
Summers, B. S., on theories and facts relating to cast iron and steel, 240.
Sundheim, Guillermo, on the world's production of manganese ore, 527.
Sutherland, D. A., on petroleum in Roumania, 360.
Swank, James M., on the world's production of steel, 526.
Sweden, iron ore of, 315.
Sweden, iron trade statistics of, 520.
Sweden, production of coal in, 521.
Sweden, shipments of iron ore, 521.
Swedish iron metallurgy and its application to Canada, 522.
Swedish iron, the composition of, 418.
Switzerland, iron ore in, 317.
Switzerland, production of coal in, 522.

**Syed Ali Bilgrami**, *paper* on "The iron industry in the territory of His Highness the Nizam of Hyderabad Deccan," 65; geological history, 65; the Gondwana series, 69; the Deccan trap, 72; the laterite, 73; alluvial deposits, 74; iron ore, 75.—*Discussion:* H. Bauerman, 88; R. Price-Williams, 88.—*Correspondence:* C. von Schwarz, 89; H. G. Turner, 99.
Sykes, Edwin, elected member, 7.

T.

TAKANO, SHIU-ICHI, on petroleum in Japan, 361.
Taylor, G., on coal screening and washing, 392.
Testing machines, 466.
Tests of coal, 339.
Tests of steel, 469.
Texture of iron, 451.
Thallner, O., on crucible steel, 427.
Thallner, O., on the composition of Swedish iron, 418.
Theories and facts relating to cast iron and steel, 240.
Theory of deformation of metals, 457.
Thering, V., on the use of blast-furnace gas, 404.
Thiem on electricity in mines, 373.
Thiessen, A. M., on the magnetic properties of iron and steel, 453.
Thiriart, Léon, on shaft sinking, 367.
Thomson, F. F., on electricity in mines, 372.
Tin plates, manufacture of, 449.
Titaniferous magnetites, 307.
Titanium and vanadium, determination of, 489.
Tomlinson, H. J., on the magnetic properties of iron and steel, 455.
Tone, F. J., on the use of carbide of silicon, 443.
Torsion and recalescence of steel, 466.
Trasenster, Paul, on the Russian iron industry, 516.
Transverse tests of cast iron, 468.
Tschernoff, D., on damask steel, 445.
Tubes for boring, 362.
Tudhope, James, elected member, 7.
Tunis, iron ore in, 324.
Turnbull, Nicholas King, elected member, 7.
Turnbull, Nicholas King, on rod-rolling, 420.
Turner, H. G., on India as a centre for steel manufacture, 99.

U.

UEHLING pyrometer, 341.
Underground haulage, 371.
United Kingdom, iron trade statistics of the, 494.
United States, blast-furnaces of the, 523.
United States, coke production of the, 524.
United States, iron trade statistics of the, 523.
United States, mineral statistics of the, 523.
Upper Silesia, mineral statistics of, 506.
Ural, firebrick manufacture in the, 337.
Ural Mountains, iron ore in the, 311.
Urban, Hans, on petroleum in Roumania, 361.

Use of coke for boiler-firing, 357.
Use of coke-oven gas for illuminating purposes, 356.
Use of petroleum in the manufacture of sheet iron, 362.
Utah, coal in, 349.
Utilisation of fine coal, 393.

V.

VALKENBORGH, L. VAN, on the evolution of the blast-furnace, 408.
Van den Broeck, E., on firedamp outbursts, 383.
Van den Broeck, E., on recent researches on meteorites, 325.
Vaughan, J., on winding appliances, 369.
Veith, Béla, elected member, 7.
Ventilation of collieries, 381.
Ventilation of iron ore mines, 331.
Verwer, H., on the determination of iron, 490.
Victoria, mineral statistics of, 496.
Villain, P., on iron ore in Luxemburg and Lorraine, 310.
Virginia, coal in, 350.
Virginia, iron ore in, 321.
Virginia, natural gas in, 364.
Visits and excursions, 243.
Vollkommer, J., on enamelled iron ware, 450.
Votes of thanks, 236.
Vrancken on shaft sinking, 367.

W.

WADA, T., on Japanese steelworks, 440.
Wainford, Richard Hanbury, *paper* on "A new casting-machine for blast-furnaces," 53; substitution of mechanical methods for manual labour, 53; failure of machines hitherto to meet the needs of ironmasters, 53; essential features of new machine, 55; results obtained, 55.—*Discussion:* E. W. Richards, 58; W. Hawdon, 59; Sir L. Bell, 60; J. Cooper, 61; R. A. Hadfield, 63; G. Ainsworth, 63.
Walker, A. W., on new American foundries, 414.
Walker, S. F., on the lighting of collieries, 384.
Ward, H. L., on recent researches on meteorites, 326.
Warren, W. H., on testing-machines, 466.
Warren, W. H., on the alloys of iron and nickel, 464.
Washing of Furness ore, 332.
Watts, W. L., on petroleum in California, 361.
Webb, H. S., on the magnetic properties of iron and steel, 453.
Wedding, H., on the calcination of iron ore, 334.
Wedding, H., on the magnetic concentration of iron ore, 332.
Wenström machine, 19.
West, T. D., on silicon and carbon in cast iron, 409.
West, T. D., on standard tests of cast iron, 467.
West, T. D., on tests of cast iron, 468.
Westminster, the Dean of, on the history of coal, 386.
Wetherill machine, 43.
Wheeler, E. C., on malleable castings, 415.
Wheels, 470.
White, I. C., on coal in Virginia, 350.
White, I. C., on natural gas in Virginia, 364.
Whiteside, O. E. S., on methods of working coal, 377.

Wiborgh, J., *paper* on "The use of finely divided iron ore obtained by concentrating processes," 8; I. Direct use in the blast-furnace, 8; irregularity due to adhesion of ore to stock wall or scaffolding, 10; II. Agglomeration before smelting in the blast-furnace, 12; agglomeration by heat alone without binding material, 12; consolidation of small ore with lime, 13; agglomeration of ore with carbonaceous material and coking, 13; III. Use of powdered ore in the open-hearth furnace, 15; IV. Direct reduction of pulverulent ores, 16.—*Discussion:* J. Riley, 45; G. J. Snelus, 46; Sir L. Bell, 48; J. E. Stead, 49; H. Bauerman, 51; the President, 51.—*Correspondence:* Editor *Engineering News*, 50.
Wigan, T. H., on cast iron pipes, 416.
Wigzell, Eustace, obituary notice of, 296.
Wilson on seamless tubes, 447.
Winding appliances, 367.
Winding engines, 328.
Winding ropes, 370.
Wire rope, tests of, 470.
Witze, Aimé, on the use of blast-furnace gas, 401.
Wolff, C. J., on new American foundries, 414.
Wolski, W., on tubes for boring, 362.
Wolters, on new rolling-mill engines, 422.
Wood, Daniel, elected member, 7.
Wood, E. Graham, appointed scrutineer, 5.
Working coal, methods of, 377.
Workshop at the Charlottenburg Technical High School, 450.
World's output of petroleum, 528.
World's production of coal and iron, 525.
World's production of manganese ore, 527.
World's production of steel, 526.
World's railways, 528.
World's supply of iron ore and pig iron, 526.

## Y.

YARROW, A. F., on the alloys of iron and nickel, 465.

## Z.

ZEIDLER, on the manganese ores in South Russia, 313.
Zenica and Kreka collieries, Bosnia, 390.
Zeyringer, F., on the use of blast-furnace gas, 402.
Zuber, R., on the origin of pe

Printed by BALLANTYNE, HANSON & CO.
Edinburgh & London